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Best Practices in Shared-Use High-Speed Rail Systems

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**Best Practices in
Shared-Use High-Speed Rail Systems**

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<p>16. Abstract</p> <p>A high-speed rail system is intercity passenger ground transportation that is time-competitive with air and/or auto for travel markets in the approximate range of 100 to 500 miles, and these systems are increasingly gaining attention in the United States. Many states are developing proposals for new HSR systems designed to solve critical transportation problems, especially the growing congestion on our highway and airport systems. High-speed rail is also viewed as a way to focus growth and development around stations as well as to serve as a catalyst for economic growth.</p> <p>There is significant international experience in building and operating HSR systems that can be helpful in planning U.S. systems. One of the key challenges for U.S. high-speed rail planning is to take full advantage of foreign experience while ensuring that no degradation of safety or unmitigated environmental effects result from the deployment of foreign technology in North America.</p> <p>Shared-use HSR systems are railroad infrastructure, rolling stock, and operating strategies that are used by both high-speed trains and conventional service (for example, freight, commuter rail, and intercity passenger rail).</p> <p>This research describes shared-use HSR systems, an important strategy for improving the feasibility of high-speed rail. In shared-use HSR, high-speed passenger trains use the same tracks and infrastructure as slower passenger or freight trains.</p> <p>This research report will be most interesting to HSR system planners and managers who want to learn about shared-use techniques. Because many of the strategies used in Europe were found to be based on traditional railroad engineering techniques for increasing capacity and speed, and therefore fairly well known to railroad engineers, the report will be useful to them mainly as a comprehensive listing of potential strategies for improving shared-use operations. The report will also be interesting for those who want to learn more about high-speed rail planning in general.</p>			
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EXECUTIVE SUMMARY

High-speed rail (HSR) systems are gaining increasing attention in the United States. High-speed rail is intercity passenger ground transportation that is time-competitive with air and auto for travel markets in the approximate range of 100 to 500 miles.¹

There is significant international experience in building and operating HSR systems that can be helpful in planning U.S. systems. A key challenge for U.S. high-speed rail planning is to take full advantage of foreign experience while ensuring that no degradation of safety or unmitigated environmental effects results from the deployment of foreign technology in North America.² The objective of this research project was to identify and describe infrastructure and operating practices that enable high-speed trains in European HSR systems to share tracks with other types of trains, which makes HSR systems both more feasible and effective. This report documents the research project's results.

This report will be of interest to HSR system planners and managers who want to learn about shared-use techniques, to railroad engineers who want a comprehensive listing of strategies that could be used to improve shared-use operations, and to anyone who wants to learn more about high-speed rail planning in general.

INTRODUCTION

The increasing movement of people and products at the local, regional, national, and international levels has placed extreme demands on transportation systems, especially in the developed world. Highway and air transportation system congestion are growing fast, and a transportation network developed to meet the needs of an age in which there was less travel and movement of materials, is ill-suited to today's needs.

In most metropolitan regions, there is no space available to expand highway and airport infrastructure, and there is strong environmental and political opposition when such expansion is proposed. One key to solving today's transportation problems is to develop systems that meet markets served poorly by the existing transportation infrastructure. High-speed rail fits snugly in just such a niche: the medium-distance travel market—too far to drive and too short to fly.

In Europe, HSR systems are well integrated into the urban transportation network and linked to metropolitan airports. There, on intercity corridors where rail offers door-to-door journey times competitive with air, it carries a large market share.³ In Continental Europe, a vast network of national high-speed train systems has nearly eliminated air trips between cities less than 400 miles apart.⁴ The Eurostar train travels between Paris and London in about three hours, which has significantly reduced air travel in the market.

As U.S. cities become denser, the demand for an improved medium-distance transportation system like HSR increases. By providing competitive travel times in a high-quality environment, HSR can attract significant numbers of passengers. This also benefits society by freeing space on the existing transportation systems for travel that has no other practical alternative, for example, allowing airports to focus on serving long-distance travel.⁵

HIGH-SPEED RAIL EXPERIENCE

The first HSR line was Japan's Shinkansen service between Tokyo and Osaka, which opened in 1964 with a maximum speed of 130 mph (210 km/h). It is a dedicated HSR system, meaning that it was built especially for high-speed trains and only high-speed trains operate on it.

France took the next big step for shared-use HSR with the introduction of the Train à Grande Vitesse (TGV) program in 1981. The first TGV line, running between Paris and Lyon, was a dedicated line with shared-use segments in urban areas. It proved that high-speed rail could attract a large share of the airline passengers in medium-distance markets.

Germany's high-speed train system, the InterCity Express (ICE), began operation in 1992. Germany used a coordinated program of improvements in infrastructure, rolling stock, and service, upgrading much of the mainline track network for speeds of 125 mph (200 km/h). This allowed ICE trains to efficiently share tracks with other trains and enabled Germany to expand its HSR network quickly and cost effectively.

The only HSR system operating in the United States today is on Amtrak's Northeast Corridor. In 1968, the corridor's private sector owner introduced the Metroliner service, consisting of track improvements and new higher-speed rolling stock. The line was already electrified. The Metroliner's initial top speed was approximately 110 mph and operating speeds eventually reached approximately 125 mph (200 km/h).

Several plans for dedicated HSR systems were proposed in the United States during the 1980s and 1990s but not built. Today, most of the direct U.S. interest in HSR is taking place at the state level;⁶ 36 states are planning and making improvements to existing passenger rail networks, and 28 are developing plans for regional HSR corridors. Most of the U.S. high-speed rail planning is for systems that will operate at speeds less than 110 mph (176 km/h). These plans recommend an incremental series of capacity, speed, and safety upgrades to existing railroad lines that will enable operation of more frequent and higher-speed service. Recently, the Federal Railroad Administration (FRA) of the U.S. Department of Transportation (U.S. DOT) has developed the Next Generation High-Speed Rail Program, designed to support the states' efforts by encouraging development of modern, cost-effective technology enabling rail passenger service at speeds up to 150 mph (240 km/h) on existing infrastructure.⁷

SHARED-USE HIGH-SPEED RAIL SYSTEMS

The Federal Railroad Administration, U.S. DOT, has defined high-speed rail as self-guided intercity passenger ground transportation by steel wheel railroad that is time competitive with air and auto for travel markets in the approximate range of 100 to 500 miles (160 to 800 kilometers). This is a market-driven, performance-based definition of high-speed rail rather than a speed-based definition. It recognizes that total trip time (including access to and from stations), rather than speed per se, influences passengers' choices among transport options in a given market, and that travelers evaluate each mode not in isolation, but in relation to the performance of the other available choices.⁸

This research concerns shared-use HSR systems, that is, systems in which high-speed passenger trains use the same tracks as slower passenger and freight service. In Europe, trains that can travel at speeds greater than 150 mph commonly operate at lower speeds on shared-use track segments and use dedicated track for top speeds. Therefore, the two basic types of shared-use HSR system are total shared-use—high-speed rail systems that share tracks with other trains over their entire length—and partial shared-use—high-speed rail systems that operate on dedicated HSR track for part of their route and share track in some locations.

The choice between a completely dedicated track system (New HSR) and the two types of shared-use depends on the travel market to be served, since there is an effective maximum speed for each type of system. A dedicated track system provides the fastest travel times, so it serves the longest travel markets; a partial shared-use system provides middle-range travel times and serves middle-range markets (the higher the proportion of dedicated track, the longer the market served); a total shared-use system provides the longest travel times and serves the shortest markets. Because it is not always feasible to construct a dedicated system, shared-use HSR systems are common throughout the world.

Problems with Shared-Use Operations

Five problems with shared-use HSR systems are safety at higher speeds; lessened train capacity; reduced top speed, which increases travel times; congestion on the line, which can increase reliability problems; and fewer options for high-speed vehicle design. These problems also impact HSR economics; for example, reduced speed makes the HSR system less attractive to customers and increases costs to operators by reducing the productivity of expensive rolling stock.⁹

Benefits of Shared-Use Operations

The four main benefits of shared-use are lower costs; reduced economic, environmental, and social impacts; improved accessibility, since shared-use enables HSR trains to go to rail stations in the hearts of cities; and network benefits, as other lines can feed traffic onto the HSR lines. All

other things being equal, it is more feasible to develop a shared-use HSR system than a dedicated HSR system. A shared-use HSR system can be improved incrementally by building dedicated segments over time as ridership increases and benefits become better known.

RESEARCH OBJECTIVE AND METHODOLOGY

The objective of this research project was to identify infrastructure and operating strategies used by European railroads to improve operation of shared-use high-speed rail systems. The research consisted of a literature review and interviews of experts. A list of interviewees is included as Appendix A. The questionnaire developed for the interviews is included as Appendix B.

This research started with the premise that there might be European strategies and practices that were unknown in the United States, or that there might be some novel application of strategies in Europe. However, it appears that Europe uses the same techniques known to improve track sharing in the United States, although these techniques are applied to different degrees based on differences in operating railroads and railroad markets. Therefore, the research focused on how the strategies are applied, the importance of various strategies, and recommendations from planners who have experience building and operating shared-use high-speed rail systems.

RECOMMENDED SHARED-USE STRATEGIES

The objective of this research was to identify infrastructure and operating strategies that improve the operation of shared-use HSR systems. One critical finding is that strong partnerships are needed to make shared-use work, and getting the parties to look beyond their own parochial interests is critical to success.¹⁰

This research identified four categories of strategies to improve the operation of shared-use HSR systems: planning, infrastructure, communications and signal system, and operating strategies. This section presents a brief outline of the recommended strategies in each category; the strategies are described in detail in Chapters 4, 5, 6, and 7.

Planning Strategies

Planning is particularly important in developing shared-use HSR systems for five reasons: often there are a large number of stakeholders; understanding railroad capacity and operation is not simple; safety issues are paramount; railroad infrastructure is highly interrelated; and railroad infrastructure is expensive. The planning process should identify the most effective set of improvements necessary to provide the service demanded by the market with the least economic, political, technological, and environmental cost.¹¹

Infrastructure Strategies

Infrastructure strategies are presented for track, structures, stations, and grade crossings. Most of the recommended strategies are similar to those used to increase capacity and speed on any rail system.

Communications and Signal System Strategies

Signals are critical in determining a rail segment's maximum speed and capacity because they control the movement of trains. Signals prevent trains from colliding on the same track and when changing tracks, and they route trains onto the best tracks to enable efficient railroad system operation.

Operating Strategies

Operating strategies are plans for providing transportation services on the shared-use segments of track. There are two types of operating strategies—operations planning and dispatching. Operations planning consists of developing a schedule for all trains that will run on the shared-use segment. Except for relatively simple systems, this usually requires the use of train simulation software. Dispatching is the process of providing trains with specific directions that account for day-to-day operating conditions in real time. The dispatching process focuses on what happens when things do not work as planned because of train delays or infrastructure failures. Shared-use HSR systems should have centralized train control, but CTC only enables dispatchers to route trains through the network; people must set priorities and make good decisions.

FURTHER RESEARCH

Two areas that would be fruitful for additional research would be policy questions and experience implementing shared-use HSR systems. A good example in the policy area would be, “What are the competitive advantages to freight railroads gained by having the public sector construct new facilities and track?”¹² On the practical side, information on experiences in implementing programs such as the Pacific Northwest Corridor or Midwest Rail Initiative would be useful for planners on other corridors.¹³

CHAPTER 1. INTRODUCTION AND METHODOLOGY

High-speed rail (HSR) systems are gaining increasing attention in the United States. A high-speed rail system is intercity passenger ground transportation that is time-competitive with air and auto for travel markets in the approximate range of 100 to 500 miles.¹⁴ Many states are developing proposals for new HSR systems designed to solve critical transportation problems, especially growing congestion on highways and airport systems. High-speed rail is also viewed as a way to focus growth and development around stations and as a catalyst for economic growth.¹⁵

The significant international experience in building and operating HSR systems can be helpful in planning U.S. systems. However, it is important to ensure that no degradation of safety or unmitigated environmental effects result from the deployment of foreign technology in North America.¹⁶ The objective of this research project was to identify and describe infrastructure and operating practices that enable European HSR systems to share tracks with other types of trains, a practice that makes HSR systems both more feasible and effective. This report documents the results of the research project.

This research report will be most interesting to HSR system planners and managers who want to learn about shared-use techniques. Because many of the strategies used in Europe are based on traditional railroad engineering techniques for increasing capacity and speed, and, therefore, are fairly well known to railroad engineers, the report will be of interest to them mainly as a comprehensive listing of potential strategies for improving shared-use operations. The report will also be of interest to those who want to learn more about high-speed rail planning in general.

This chapter summarizes the research purpose and the methodology used to complete the research and outlines the report contents.

RESEARCH PURPOSE

High-speed rail systems can lessen some of the major transportation problems facing the world today, such as the increasing congestion at airports and on air routes, highway congestion, and increasing energy use. Shared-use is an important high-speed rail strategy because often it is the only feasible way to construct a high-speed rail system.

The objective of this research project was to identify infrastructure and operating strategies used by European railroads to optimize operation of high-speed trains on shared track segments. All Europe's high-speed rail systems operate to some degree on shared-use track; therefore, European railroads have a great deal of experience in planning and improving such systems.

This research started with the premise that there might be European strategies and practices that were unknown in the United States, or that there might be some novel application of strategies in Europe, but this was not the case. It appears that the same techniques known to improve track sharing in the United States are used in Europe but to different degrees based on differences in operating railroads and railroad markets. This is logical, since the basic problems with shared-use HSR are similar to those for any railroad: safety, capacity, and speed. Furthermore, Amtrak's Northeast Corridor (NEC) is, by many measures, one of the most complex and heavily used shared-use HSR systems in the world. Many of the techniques and strategies used in European systems have been used for many years on the NEC.

Since the strategies used by European railroads do not differ significantly from those used in the United States, the research focused on how the strategies are applied, the importance of various strategies, and recommendations from planners who have experience building and operating shared-use high-speed rail systems.

It is hoped that this research will provide planners with an approach to planning high-speed rail systems, a set of techniques that can be used in designing and operating the system, and a context for making shared-use feasibility decisions. The report will be most useful as an introduction to the topic of shared-use high-speed rail systems for policymakers and as a summary of shared-use strategies for planning and evaluating new high-speed rail systems. Since most of the strategies described in the report will be familiar to railroad engineers, the report will be most useful for them as a comprehensive summary of shared-use techniques.

METHODOLOGY

The research consisted of a literature review and expert interviews. Technical experts from European railroads, European railroad research institutes, Amtrak, the U.S. Federal Railroad Administration, U.S. railroad planners, and other interested parties were interviewed. An initial set of interviewees was developed working with staff from the California High-Speed Rail Authority and the Swiss Federal Institute of Technology's IVT. Those interviewees then provided names of additional experts to interview. A list of interviewees is included as Appendix A.

The interviews were completed between January and August 2002. A questionnaire was developed to introduce the subject and set the context for the interviews, but it was not followed strictly because the project's objective was to obtain a qualitative understanding of shared-use techniques. A copy of the initial questionnaire is included as Appendix B.

Information from the interviews was used to prepare a draft report. The draft benefited from comments by Steve Colman, an Assistant Professor in Transportation at San José State University, as well as an independent peer review, but any errors or omissions are the fault of the author.

It must again be emphasized that this report was not designed to provide detailed technical data, but to provide qualitative information on the subject of track sharing by high-speed rail, introduce the subject of track sharing, make recommendations for use in the planning process, and suggest paths for future research.

REPORT OUTLINE

This report begins with the Executive Summary.

Chapter 1 is this introduction.

Chapter 2 describes the state of high-speed rail today. It includes a definition of high-speed rail; a brief history of high-speed rail throughout the world; and a description of current high-speed rail planning, with an emphasis on the United States.

Chapter 3 describes track sharing in detail: the institutional issues surrounding it, its types, problems associated with it, and its benefits.

Chapter 4 describes best practices for planning shared-use high-speed rail systems. All the interviewees emphasized the need for strong planning. This chapter describes the importance of planning, outlines the shared-use high-speed system planning process, and presents a set of planning recommendations.

Chapter 5 presents strategies for improving shared-use high-speed rail system infrastructure, including track improvements to increase capacity, track improvements to increase speed, station improvements, and grade-crossing improvements.

Chapter 6 presents strategies for improving communications and signaling systems on shared-use high-speed rail systems. Communications and signal systems include signaling, train control, and traffic control systems. The chapter outlines these systems and presents recommendations for each of them.

Chapter 7 presents operating strategies to improve shared-use high-speed rail systems. It includes recommendations for planning operations (in advance) and for real-time control of shared-use high-speed rail systems.

Appendix A lists the persons interviewed for this project.

Appendix B presents the initial questionnaire that was used to conduct the interviews.

A bibliography, a list of acronyms, and endnotes are also included in this report.

CHAPTER 2. HIGH-SPEED RAIL

High-speed rail systems are increasingly viewed as an attractive means for serving medium-distance transportation markets. This chapter presents an introduction to high-speed rail systems, with sections on the definition of high-speed rail, factors related to travel speed, the importance of high-speed rail, worldwide experience with high-speed rail, and high-speed rail planning in the United States.

A NICHE FOR HIGH-SPEED RAIL

One fundamental change caused by globalization and the communications revolution is the increasing movement of people and products at the local, regional, national, and international levels. This has placed extreme demands on transportation systems, especially in the developed world. Highway and air transportation system congestion are growing fast, and travel demand sometimes seems almost unlimited. As the “paperless” office has not eliminated paper, the communications revolution seems to have actually increased the demand for travel.

Extreme congestion is a sign that the transportation system cannot cope with the demands of a new world. The transportation network has been developed to meet the needs of an earlier age, one in which there was less travel and movement of materials, and is, therefore, ill suited to meet today's needs. The existing system is not specialized enough to serve new transportation demands efficiently. For example, it may be efficient to drive 120 miles when there is limited congestion, but it makes a great deal less sense in highly congested areas.

The key to solving today's transportation problems is to develop systems that meet markets served poorly by the existing transportation infrastructure. High-speed rail fits snugly in such a niche, namely the medium-distance travel market: too far to drive and too short to fly. Highway congestion and airport access delays have conspired to create this niche by increasing travel times on these networks. Congestion and delays will grow with the economy, further improving the prospects for high-speed rail during the coming years.

A fundamental problem with today's highway and airport infrastructure is that these networks cannot be expanded significantly. In most metropolitan regions, there is no space available and there is strong environmental and social opposition to the expansion of highways and airports. A closely related problem that causes society to invest inefficiently in transportation systems is the political inability to create a market for transportation infrastructure. Selling highway use or airport use in a market would reduce their demand and increase demand for other transportation systems such as high-speed rail. Using market pricing for highway and airport infrastructure would send stronger market signals for development of an HSR network than can be provided solely by the increases in travel time caused by delay and congestion on those systems.

European experience with high-speed rail points to a good future in the United States. In Europe, HSR systems are well integrated into the urban transportation network and linked to metropolitan airports. There, rail carries a large market share on intercity corridors where it offers door-to-door journey times competitive with air.¹⁷ According to the *New York Times*, in Continental Europe, a vast network of national high-speed train systems has nearly eliminated air trips between cities less than 400 miles apart.¹⁸ High-speed rail networks “bleed the short-haul capacity out of the system,” freeing airports to do what they do best: handle long-distance trips.¹⁹

One key difference between U.S. and European transportation systems is land use patterns; however, these patterns are becoming more similar—European cities are spreading out, and major U.S. cities are becoming denser. This evolving land use pattern supports the demand for an improved medium-distance transportation system, such as high-speed rail, by creating stronger nodes in the United States, increasing highway congestion, and further reducing the ability to build new highways and airports.

To summarize, high-speed rail fills an important and growing role in the transportation market. By providing competitive travel times in a high-quality environment, it can attract significant numbers of passengers. This also benefits society by freeing space on the existing transportation systems for travel that has no other practical alternative, for example, allowing airports to focus on serving long-distance travel.²⁰

DEFINITIONS: HIGH-SPEED RAIL AND SHARED-USE

The Federal Railroad Administration (FRA) and U.S. Department of Transportation (DOT) has defined high-speed rail as self-guided intercity passenger ground transportation by steel wheel railroad that is time competitive with air and/or auto for travel markets in the approximate range of 100 to 500 miles (160 to 800 kilometers). This is a market-driven, performance-based definition of high-speed rail rather than a speed-based definition. It recognizes that total trip time (including access to and from stations), rather than speed per se, influences passengers’ choices among transport options in a given market, and that travelers evaluate each mode not in isolation, but in relation to the performance of the other available choices.²¹

Using a market-based definition helps explain why the opportunities and requirements for high-speed rail differ markedly among different city pairs and transportation corridors. A particular high-speed rail system might be effective in one corridor but fail in another simply because it did not meet the corridor’s particular market demand. Adopting a shared-use strategy is an excellent example of this point; in some markets it will be successful but not in others.

The international organization of railways, the Union Internationale Chemins de Fer (UIC) High-Speed Rail Task Force, has decided to use the plural word “definitions” for high-speed rail to reflect the fact that there can be no standard definition based on infrastructure, rolling stock, and

operations. The task force developed definitions for high-speed rail in all three of these areas.²² The UIC also emphasizes that high-speed trains need to provide high-quality service, a further reflection on the market-based nature of successful high-speed rail systems.

The FRA has defined two categories of high-speed rail service based on top speed: Accelerail and New HSR.²³ These categories are important because they define the system's basic characteristics, including infrastructure, rolling stock, and operating regulations. They are defined as follows:

- **Accelerail**—High-speed rail systems that travel at speeds around 90 to 150 mph (144 to 240 km/h). These systems are designed to share tracks with other types of trains.
- **New HSR**—High-speed rail systems that travel at speeds above 150 mph (240 km/h). To reach these speeds, a dedicated line and highly specialized infrastructure and rolling stock are needed. The only totally dedicated system now operating is Japan's Shinkansen service.

The Accelerail category can be further subdivided based on speed into rough categories of less than 110 mph (176 km/h), 110 to 125 mph (176 to 200 km/h), and 125 to 150 mph (200 to 240 km/h). These categories are based on practical and regulatory infrastructure and rolling stock requirements. The maximum practical speed for Accelerail today is approximately 110 mph (176 km/h). Operating in the higher-speed categories, such as on Amtrak's Northeast Corridor (top speed of 150 mph), requires more specialized rolling stock (for example, turbine propulsion or electric locomotives), higher-quality track, more advanced signal systems, and elimination of grade crossings. Speeds over approximately 125 mph require electrification.

This research concerns shared-use HSR systems—systems where high-speed passenger trains use the same tracks as slower passenger and freight service. The ability of trains to operate in shared-use systems generally becomes more difficult as train speed increases. However, it is common in Europe for trains that can operate at very high top speeds (that is, over 150 mph) to operate on both shared-use and dedicated tracks. These trains operate at lower speeds on shared-use segments and at top speeds on the dedicated track segments. Since this type of operation can also be described as shared-use, it is possible to define two basic types of shared-use HSR systems:

- **Total Shared-Use**—High-speed rail systems that share tracks with other trains over their entire length, such as Amtrak's Northeast Corridor and most of the Accelerail proposals.
- **Partial Shared-Use**—High-speed rail systems that operate on dedicated HSR track for a portion of their route and only share track in some locations, such as France's TGV system and the California High-Speed Rail Authority's HSR Plan.

Choosing between a completely dedicated track system (New HSR) and the two types of shared-use is the fundamental question in designing an HSR system. The choice depends on the travel

market to be served because there is an effective maximum speed for each type of system. A dedicated track system provides the fastest travel times, so it serves the longest travel markets; a partial shared-use system provides middle-range travel times and serves middle-range markets (the higher the proportion of dedicated track, the longer the market served); a total shared-use system provides the longest travel times and serves the shortest markets.

There are a few examples of non-high-speed trains using dedicated HSR track segments. For example, Spain's AVE tracks between Madrid and Seville are used by TALGO overnight service, with the TALGO trains operated at lower speeds during periods of low AVE train service.

THE SPEED FACTOR

The market-based definition of high-speed rail emphasizes door-to-door travel time rather than speed as the key factor of customer interest in high-speed rail systems, but, of course, travel time is closely related to speed. Given speed's importance in high-speed rail system planning, there are three important factors that should be kept in mind when considering HSR systems.²⁴

First, increases in maximum speed have decreasing marginal gains in travel time savings. This means that a 10-mph increase in speed between 80 and 90 mph will reduce total travel time by relatively more than a 10-mph increase in speed between 140 and 150 mph. Therefore, improving the speed of a slow train can have a greater travel time benefit for passengers than improving the speed of a fast train.

Second, travel time reductions due to higher speeds depend very much on the distance between stations because trains need a significant amount of time to accelerate to their maximum speed and to decelerate and stop. Trains that stop and start frequently never reach their maximum speeds or reach it only for a short period of time. For planning purposes, this means that HSR systems are not cost effective on lines with frequent station stops.

Third, the marginal cost of increases in maximum speed (in system design, construction, operating costs, and so forth) grows more than proportionately with speed increases. In other words, the level of infrastructure investment increases significantly as the maximum speed increases. This is partly because of the increased level of precision required in all aspects of the HSR system. Energy consumption also increases with the speed because of the exponential increase in air resistance. For high-speed rail planning, this means that the maximum speed necessary to serve the market must be carefully analyzed because each increase in speed is more expensive in capital and operating terms.

These three factors, along with market demand, should be used early in the planning process to develop and evaluate high-speed rail plans at the conceptual level before proceeding with more

detailed planning efforts. They also help to explain the strong interest in the Accelerail category of high-speed rail in many U.S. regions.

WORLDWIDE EXPERIENCE

The first true high-speed rail line was Japan's Shinkansen service between Tokyo and Osaka. This line was opened in 1964 with a maximum speed of 130 mph (210 km/h). The line has been extended and its maximum speed increased to 188 mph (300 km/h). Today it carries more than 400,000 passengers per day.²⁵ The Shinkansen line is a dedicated high-speed rail system, meaning that it was built especially for high-speed trains and no other types of trains operate on the line. One reason the Japanese decided to build a dedicated line was that there was no capacity on the existing railroad network available for adding high-speed trains.

During the 1960s, researchers from several countries experimented with technologies that would enable trains to travel at higher speeds on the existing network, in other words, shared-use high-speed rail systems. Both Britain and France experimented with tilting trains and infrastructure improvements to existing lines.²⁶ France made significant progress in increasing speeds during this time by improving its signaling system and infrastructure.²⁷

A well-known problem with high-speed rail service was that operating trains at high speeds caused significant track damage. Therefore, there was an intensive research effort to design trains that could travel at high speeds without damaging the tracks.²⁸ France was the first country to put these newly designed trains into service with its Train à Grande Vitesse (TGV) program.

The first TGV line was opened between Paris and Lyon, a distance of 260 miles (417 km) in 1981. It was a dedicated line with shared-use segments in urban areas. Trains operated at a maximum speed of 170 mph (270 km/h), and the system was successful technically and financially.²⁹ The line also proved that high-speed rail could attract a large share of airline passengers in medium-distance markets. Based on this line's success, France embarked on an extensive program of building high-speed lines throughout the country, and French technology is used on many other high-speed rail systems worldwide (see Figure 1).

The TGV is a partial shared-use high-speed rail system because it uses both dedicated high-speed tracks and shared-use tracks. On shared-use segments, it travels under the same restrictions as other trains; on the dedicated segments, it now reaches top speeds of 188 mph (300 km/h) on some lines. France has continued to improve its system, adding new lines and technical improvements to the TGV trains themselves. Today's TGV trains are faster, more comfortable, and more efficient than the original trains, and there is even a double-deck version on the heavily traveled Atlantique line.³⁰



Figure 1. French TGV Train
Source: SNCF

Britain also developed a high-speed rail program during the 1960s. The British HST125 trains have been successfully operated for more than 25 years. These trains are especially interesting since they are diesel powered.³¹

The high-speed program in Germany included extensive work to upgrade many of its mainline tracks for speeds of 125 mph (200 km/h), continuing an earlier effort to improve the nation's railroad network. This later effort comprised a coordinated program of improvements in infrastructure, rolling stock, and service (for example, hourly service on an intercity network throughout the country).

In parallel with these improvements to the rail network, Germany began developing a true high-speed system, the InterCity Express (ICE), although service did not begin until 1992, more than 10 years later than the TGV. The first ICE lines were between Hannover and Würzburg and between Mannheim and Stuttgart. The first-generation ICE trains had a maximum line speed of 156 mph (250 km/h)³² but could travel up to 280 km/h to make up schedule delays.

Germany's approach of upgrading its main track network allowed ICE trains to share tracks with other trains efficiently and enabled Germany to expand its high-speed network quickly and cost

effectively. Today Germany is building new, dedicated high-speed tracks along many shared track segments to improve service by adding capacity and increasing speed. Germany has also continued development of the ICE trains and has developed a tilting version (ICE-T) for use on lines with many horizontal curves, as well as faster versions. The latest-generation trains (ICE3) travel at speeds above 200 mph (330 km/h).³³

The ICE trains have increased passenger volumes significantly in Germany. In one example, shortening the travel time between Hamburg and Frankfurt by one hour increased the number of passengers by nearly 40 percent.³⁴ Surveys show that the ICE trains are being used by passengers traveling longer distances than conventional InterCity services.

Spain opened its first high-speed rail line in 1992, in connection with the World Fair in Seville (see Figure 2). The line between Madrid and Seville is interesting because although it was built for high-speed rail trains (the AVE system), it allows some other trains to use the dedicated high-speed line (for example, the TALGO overnight service from Barcelona). The AVE is also remarkable because it has adopted the common European track gauge rather than the standard Spanish gauge, which is wider. Similarly, the Italian high-speed lines were built for high-speed service, but other trains are allowed to use the line.

As an example of extending high-speed networks, the Thalys high-speed trains serve a network including France, Belgium, The Netherlands, and Germany. The Dutch trains run on existing tracks with other passenger and freight service, operating as regular passenger trains. In 2006, a new dedicated high-speed line will be opened to allow the trains to operate at higher speeds (188 mph or 300 km/h).³⁵ The Thalys rolling stock must be designed to operate on all four countries' different signaling and power distribution systems.

One major project that deserves recognition is the English Channel Tunnel high-speed line that opened in 1994. This impressive engineering project has provided excellent rail service between the European continent and Great Britain, significantly reducing travel times and attracting a large number of former air passengers.³⁶ The system is directly linked to France and Belgium's HSR network and will be further improved upon completion of a new 60-mile dedicated high-speed rail segment between the tunnel and London, which will cost about 6 billion pounds.³⁷



Figure 2. Spanish AVE Train
Source: Bombardier Transportation

As this brief survey indicates, there has been much activity in developing high-speed rail systems in Europe. There are two key reasons for this: Europe contains many large city-pair markets that can be served easily by HSR, and Europe has a long history of support for intercity passenger rail services. Because high-speed rail is important in Europe, the European Commission adopted a European high-speed network. In most cases, the European network links the individual national systems into an integrated network, as shown in Figure 3.



Figure 3. European High-Speed Rail Network
Source: MTI

Over this same period, interest in high-speed rail was increasing in the United States, although the only U.S. high-speed rail system implemented has been the shared-use system on the Northeast Corridor (NEC) between Boston and Washington D.C. NEC improvements started in the late 1960s with the Metroliner program and continued sporadically until implementation of the Acela Express in late 2000. The Metroliner operated with a top speed of approximately 125 mph, while the Acela Express has a top speed of 150 mph (240 km/h). Amtrak's Acela Express program included upgrading the infrastructure and acquiring new rolling stock that can travel faster on the shared-use tracks.

One of the most interesting aspects of the NEC, for purposes of this research, is the level of complexity experienced in planning and operations because of the many different types of trains operated on the line. Hundreds of 80-mph commuter trains and 30-mph freight trains must share

the tracks with Acela Express trains operating between 110 and 150 mph. By many measures, there is more shared-use on the NEC than on most European lines. Given this wealth of shared-use experience, many of the research recommendations come from those familiar with the NEC. Amtrak reports that several European high-speed rail operators are studying the NEC to learn more about shared-use operations.³⁸

Amtrak's Acela Express has proved very popular, especially in the wake of the September 11, 2001, terrorist attacks, when ridership soared by 40 percent.³⁹ The service is currently carrying more than 50 percent of the air/rail market between New York and Washington and more than 30 percent of the market between Boston and New York. The service is popular with passengers, but it has been plagued by a series of technical problems, starting with delayed introduction; in late 2002, many trips were canceled because of yaw damper bracket cracks. Many critics blame these problems on vehicle design, specifically the excessive weight needed to meet FRA crashworthiness standards.⁴⁰

In the 1980s and 1990s, several plans for high-speed service in the United States were developed but not built. These included proposals for high-speed rail in California, the Texas Triangle plan, and Florida's FOX system. However, many high-speed rail plans are now under development in the United States. These efforts are outlined in the following section.

UNITED STATES HIGH-SPEED RAIL PLANNING

U.S. interest in high-speed rail has increased significantly during the 1990s, both because of foreign success and the increasing congestion in the air and on the road. The landmark Intermodal Surface Transportation Efficiency Act (ISTEA) in 1991 required completion of a nationwide high-speed rail study and designation of five high-speed rail corridors, and included funding for high-speed rail projects.⁴¹ This was followed by 1994's Swift Rail Development Act, which led to the establishment of the FRA's Next Generation High-Speed Rail Program.

The Next Generation High-Speed Rail Program was designed to support the availability of modern, cost-effective technology enabling rail passenger service at speeds up to 150 mph (240 km/h) on existing infrastructure. The program focuses on three main areas: track evaluation, improvement, and maintenance; signaling and communications; and non-electric motive power. This focus was continued in the 1998 Transportation Equity Act for the 21st Century (TEA-21).⁴²

Since TEA-21, several other high-speed rail bills have been considered by the Congress, including bills that would provide additional funding for high-speed rail. Today, 36 states are planning and making improvements to existing passenger rail networks, and 28 are developing plans for regional high-speed rail corridors.⁴³ Figure 4 shows current U.S. high-speed rail planning efforts.



Figure 4. Current High-Speed Rail Planning in the United States
Source: U.S. DOT-FRA

The main reasons for increased interest in high-speed rail systems are that they can provide comfortable, high-quality transportation in the medium-distance travel market and reduce congestion on the highway and airline system. Another reason is the time necessary to complete additional security requirements when flying following the September 11, 2001, terrorist attacks.

Unlike earlier planning efforts for dedicated HSR systems such as the Texas and Florida projects, most current planning is for shared-use HSR systems that will operate in the Accelerail range of speeds. Much of the current U.S. passenger rail planning is focused at the state level.⁴⁴ According to Amtrak, states are largely driving the effort—they have consistently concluded that improved passenger rail service often is the only viable and affordable alternative to the highway and airport congestion that is choking economic growth.⁴⁵ Some examples of planning efforts recently completed or currently underway include:⁴⁶

- California Passenger Rail System—20-Year Improvement Plan⁴⁷
- Midwest Regional Rail Initiative⁴⁸

- Amtrak Cascades (Oregon-Washington) Plan⁴⁹
- Boston–Montreal High-Speed Corridor⁵⁰

All these plans recommend a series of capacity, speed, and safety upgrades to existing railroad lines that will enable operation of higher-speed service. Coupled with these infrastructure improvements are recommendations for increased levels of service and the purchase of new rolling stock that is both more attractive for passengers and capable of operating comfortably at higher speeds.

These plans all focus on systems operating at less than 110 mph (176 km/h). One reason for focusing on this speed is that the required grade-crossing safety improvements for trains traveling at higher speeds are still difficult to meet, and most existing railroad lines have grade crossings. The FRA is participating in several research projects designed to improve grade-crossing warning devices, and as new solutions are developed, higher-speed services may be considered.⁵¹

These plans recommend an incremental upgrade program with targets for infrastructure improvements and service levels given over time, often over a 20-year period. This is a sensible approach to improving an infrastructure system as complex and interrelated as the railroad network. An incremental improvement program can begin providing benefits immediately and is more consistent with annual capital spending programs developed through legislation.

While these Accelerail plans focus on speeds less than 110 mph, they could be upgraded in the future by further improving the infrastructure and rolling stock or by adding sections of dedicated track. The FRA's *High-Speed Ground Transportation for America* report suggests that states fine-tune their corridor studies to maximize the cost effectiveness of HSR improvements. It suggests careful attention to the possibility of staging (gradual implementation of more ambitious HSR solutions) and routing options (building dedicated routes). The report suggests that such improvements, if designed with vision, could become the kernel for a much improved HSR system.⁵²

The state of California has adopted just such an approach in its exciting plan for a new HSR-type system between San Francisco and Los Angeles. This system would be similar to European systems such as the TGV and ICE in that it would combine long sections of dedicated track (where it would operate at speeds on the order of 200 mph [320 km/h]) with shared-use sections.⁵³ The main reason California is considering a new HSR-category system is that its major market, between San Francisco and Los Angeles, is too long (approximately 380 miles) to be served by trains in the Accelerail category. California's HSR system has a travel time goal of 3 hours for express trains from San Francisco to Los Angeles.

The California HSR system would share tracks with freight, commuter, and other intercity trains in the vicinity of San Francisco and Los Angeles, where it would be difficult and expensive to

obtain rights-of-way needed to build dedicated tracks. The system would be closely coordinated with the state's other intercity passenger rail service and urban transit systems. Eventually, it might consider a more extensive track-sharing program to provide service throughout the state.

CHAPTER 3. SHARED-USE HIGH-SPEED RAIL SYSTEMS

Chapter 2 presented a definition of shared-use HSR systems. This chapter outlines some of the institutional issues surrounding planning and operation of shared-use HSR systems, the problems with shared-use, and the benefits of shared-use.

INSTITUTIONAL ISSUES

An interesting aspect of planning a shared-use HSR system is that, because of its shared nature, several different organizations will be involved in operating trains over the network. Most of the challenges to developing HSR systems are not technological, but political, institutional, and financial.⁵⁴

According to one source, “Clearly, the institutional barriers, or perhaps attitudinal barriers, are the largest problems for shared-use partners.” Getting the parties to look beyond their own parochial interests is critical to success.⁵⁵ An agency that wants to introduce shared-use HSR service must carefully consider process issues and techniques that enable the formation and operation of fruitful multiagency partnerships.

Some of the partners may not be obvious; as one interviewee stated, “Every city on the corridor will want something.”⁵⁶ The general public will also be involved in developing the system and must be consulted if the project is to be successful. An especially interesting institutional issue is the question of competitive benefits that government-sponsored improvements on a shared-use infrastructure may provide to the private-sector infrastructure owner (for example, a freight railroad).⁵⁷ Analyzing these institutional issues will be an important area of future research.

Because the biggest challenges will be institutional, the first step in any shared-use HSR planning effort must be a careful assessment of institutional issues and development of a plan to address them. Many different techniques should be considered in developing this plan, including use of facilitation, identifying champions, public involvement and communications, and mediation, but recognizing that this step is necessary is the most critical.

One good technique in developing a shared-use HSR plan is to organize a steering committee of partners for the project. At first, this group will be responsible for developing the implementation plan, but it will continue to be needed to resolve operating issues and develop further improvement plans. When organizing these groups, it is critical that all participants understand the decision-making and plan implementation process.⁵⁸ A good description of the role of partners is presented in the TRB’s Intercity Passenger Rail Committee newsletter article, “Partners Key to Rail Service in Puget Sound Corridor.”⁵⁹

In some ways, the existing institutional structure might not work to improve passenger rail service in the corridor. In that case, it may be necessary to consider new and innovative organizational schemes. Europe is experimenting with different ways to allow open access to the traditionally national-government-controlled railroad system.⁶⁰ Others have suggested different ways of organizing Amtrak and Northeast Corridor service in the United States to improve rail service. These reorganization efforts should be considered early in the planning process.⁶¹

When working in the existing institutional structure, the involvement of multiple and different organizations is a departure from the traditional way railroads work, which adds a new dimension to planning and operating shared-use HSR systems. The three main aspects of this issue are the concept of multiple operators, the planning of multiple-operator systems, and the operation of multiple-operator systems. These are outlined below.

Concept of Shared-Use

Railroad infrastructure owners usually are responsible for operation of trains on their network, but in some cases, different organizations operate trains on the same tracks. In the United States, Amtrak, commuter rail, and freight trains—all operated by different organizations—share tracks on the Northeast Corridor. There are many examples of different operators sharing track under running powers agreements (for example, one freight railroad operating trains on another railroad's tracks).

There is growing experience with multiple companies operating trains on European railroads; in Great Britain, 14 different railroad operating companies use at least some portion of the West Coast Mainline between London and Glasgow.⁶² Shared-use is a more familiar concept in other transportation systems, such as highways and airports; there may be important lessons from the operation of these systems that can be transferred to HSR systems.⁶³

When planning shared-use systems, it is important to recognize that the concept of multiple operators may be relatively new for railroads. This means that the institutional framework has not been developed, and the intellectual understanding may not be in place, to facilitate planning and operating the shared-use system. In those cases, advocates of shared-use systems must develop a good process for stakeholders to work together before beginning the planning effort.

Planning Shared-Use Systems

There are two important institutional issues in planning shared-use high-speed rail systems. First, the infrastructure owner must be protected from capacity and safety impacts of the new system; second, a process must be in place that enables changes to be made to the existing systems to improve overall service.

In the United States, the common situation is that a government agency wants to operate passenger rail service on tracks owned by a private-sector freight railroad. Since deregulation of the rail industry, most U.S. rail infrastructure has been so closely optimized for existing needs that adding new service would create capacity problems. Therefore, infrastructure owners (generally freight railroads, but public-sector owners are just as concerned with protecting their operations as private owners) require those who want to operate new service on their line to prove that the proposed operations will not negatively impact existing service.⁶⁴ This usually means that any proposal for new service must include infrastructure improvements designed to increase line capacity and speed, with benefits accruing to both the infrastructure owners and the new operator.

As the title of a presentation made to the AREMA conference, “Running High-Speed Passenger Trains on Freight Railroad Track—or—You Want To Do What?” indicates freight railroads may not initially welcome new passenger service on their tracks. According to the paper, these tracks are “owned mostly by large corporations, run by hard-headed businessmen advised by capacity-challenged operating people and liability-sensitive lawyers in a world of congestion and spiraling jury awards. To gain the cooperation of the host freight railroad requires careful attention to design and safety issues, as well as access to tools that can demonstrate capacity-related impacts of sharing tracks.”⁶⁵ In other words, it is critical that the planning analysis, prepared by the agency that wants to operate new service, be comprehensive and include strong technical analysis, since the infrastructure owner will carefully review the analysis.⁶⁶

Second, the best way to improve operations may be to make changes to the owner’s rolling stock or operations rather than to the HSR system. In this case, the HSR operator must have good relations with the owner so that reasonable and effective solutions can be developed and implemented. For example, when installing cab signaling on freight locomotives that operate on a shared-use segment, the operators must work together to agree on installing this equipment on a reasonable number of locomotives.

Operating Shared-Use Systems

The third institutional issue is how the shared-use system will be operated. Operation issues include developing train schedules, train control (especially when there are delays or infrastructure problems), operating rules, maintenance procedures, and financing. As in planning shared-use systems, the only way to operate the system successfully is to have a good working relationship between all the stakeholders involved in operations.

TRACK-SHARING PROBLEMS

The most efficient transportation infrastructure-vehicle system operates a single type of vehicle on a guideway designed specifically for it. For high-speed rail systems, this means track, signal systems, stations, and other infrastructure coupled with trains designed especially for the

particular infrastructure. Because it is often infeasible to construct a dedicated high-speed rail system, shared-use HSR systems are common. There are five well-known problems with shared-use HSR systems:

- **Safety**—Higher speeds may increase accident severity and potential.
- **Capacity**—Shared-use reduces potential train capacity.
- **Reduced Top Speed**—Shared-use reduces potential top speeds, increasing travel time.
- **Congestion**—Shared-use increases congestion, increasing potential reliability problems.
- **High-Speed Vehicle Design**—Shared-use reduces options for HSR vehicle design.

These technical problems also have economic impacts on the high-speed rail operations. For example, the lack of capacity and low operating speeds caused by shared-use operations make the high-speed system less attractive for the customer and also increase the expense to system operators because their expensive rolling stock is less productive than it might be otherwise.⁶⁷

Safety

Safety is the most important aspect of railroad operations and planning. High-speed rail systems in operation today have excellent safety records: France's TGV system has operated for more than 20 years without a fatality. However, basic physics means that the faster a vehicle is traveling, the more damage will be done in an accident. Faster speeds also mean there is less time for operators to receive and act upon train control information. Therefore, high-speed rail vehicles and infrastructure must be designed with very high levels of safety.

One aspect of the safety problem for shared-use HSR systems is that many U.S. railroad lines now operate without any passenger service. Owners of these railroads are concerned about liability for accidents⁶⁸ because an accident involving passenger trains is likely to be more serious than one involving only freight trains. There is no reason to believe that accident frequency will increase with well-designed HSR systems, but increasing speed will increase the severity of any accidents that occur.⁶⁹ Much of the U.S. government's HSR research effort focuses on improving safety.⁷⁰

Capacity

Capacity is defined as the number of trains that can be operated over a given section of railroad track per unit of time (for example, 10 trains per hour). One significant problem in planning a shared-use high-speed rail system is lack of capacity on the shared-use segment. There are two reasons for this. First, many of the railroad lines on which one wants to add new service are already heavily used by other trains (for example, on segments near major cities), so there is little available capacity. Second, operating trains that travel at different speeds reduces capacity on a

rail line. The optimum condition—all trains operating at about the same speed—requires operation of similar types of trains.

Reduced Top Speed

Each segment of railroad track has speed limits determined by its track quality, superelevation and curvature, grade, and signaling system. A critical problem with shared-use HSR systems is that trains are limited to operating at the track segment's maximum speed, generally much less than the HSR train's potential top speed. Since the objective of a high-speed rail system is to reduce travel time, a great deal of effort is spent in developing rolling stock that can go fast. With shared-use, these carefully designed, expensive high-speed trains must travel at lower speeds on shared-use track sections. This increases travel time, which reduces market demand for the service.

Congestion

Congestion is a problem on all transportation networks that operate at near-capacity levels, which is common on shared-use HSR systems. The particular problem is that HSR customers are paying a premium for reliable service. Causes of congestion on HSR trains include lack of capacity on popular routes, the difficulty of operating different types of trains on the same infrastructure, and day-to-day schedule delays. Ideally, high-speed trains can be scheduled to reduce the impacts of congestion, but in day-to-day operations (especially on busy sections of railroads) many things can disrupt planned schedules and cause delays. An especially difficult aspect of scheduling trains is that many U.S. freight railroads do not operate trains on exact schedules (in the passenger train sense), compounding the problem of HSR scheduling.

High-Speed Vehicle Design

One goal for the design, construction, and subsequent maintenance of intercity passenger rail systems is to achieve a fully integrated vehicle-track system.⁷¹ The high-speed rail vehicles should be designed to fit closely to the infrastructure (tracks and signal systems), market needs, and operations plan. A good example of this comprehensive design process is France's TGV system. There, vehicle designers worked with infrastructure planners to optimize the overall system; thus, if it was more efficient to give a vehicle a certain quality than to achieve the same goal with infrastructure, the vehicle was designed with that quality, and vice versa.⁷²

Designing rolling stock for a newly built, dedicated high-speed line is easier than for shared-use high-speed systems because there are fewer constraints. In shared-use systems, high-speed vehicles must be designed to consider interactions with all the other types of vehicles using the system as well as the limitations to infrastructure imposed by the needs of those other vehicles.

In the United States, all rolling stock that operates on the national railroad system must meet strict crashworthiness standards (also referred to as buff strength), normally requiring use of heavy vehicles. Unfortunately, the best rolling stock for high-speed systems is lightweight, since those vehicles need less power to accelerate and less braking effort to stop, are energy efficient when traveling at high speeds, and reduce track maintenance costs. While Amtrak's Acela high-speed trains prove that the U.S. standards can be met for speeds less than 150 mph, critics of these trains argue that their heavy weight impacts operations.

For most of the shared-use HSR plans now being developed, rolling stock design will not be a significant issue. However, for systems planning to operate at speeds in the highest ranges (over 150 mph) on segments of dedicated HSR track, such as the California system, vehicle standards may pose a problem: U.S. crashworthiness standards conflict with the lightweight construction of modern high-speed passenger trains.⁷³ Adapting existing HSR equipment to meet U.S. regulations would result in weight increases that would disrupt the design integrity of the trainset.⁷⁴ The vehicles also will be more expensive to build and operate than European versions and could increase the cost of track maintenance. Finally, placing constraints on HSR vehicle design reduces the ability of planners to make the tradeoffs between infrastructure and rolling stock that have been used in developing European HSR systems.

Although safety must remain the most important factor in railroad operations, there are different ways to achieve safety objectives. One potential solution would be to adopt time separation in the shared-use segments. Under this system, high-speed trainsets that were not compliant with FRA crashworthiness standards would be operated during certain periods on shared-use segments, and standard trains (for example, freight trains) would be operated during other periods. The FRA has granted waivers to transit agencies for operating light rail vehicles on railroad tracks based on the use of temporal separation,⁷⁵ and this could work for lighter-weight HSR vehicles as well. One potential problem with temporal separation could be the inability to operate standard FRA-compliant commuter rail trains while noncompliant HSR trains were operating.

A second potential solution would be to apply a comprehensive risk analysis to operation of noncompliant HSR vehicles in a shared-use operation. One famous application of risk analysis in shared-use rail projects is in Germany, where several cities operate light rail vehicles on tracks with regular rail service (the most famous being Karlsruhe).⁷⁶ Such a risk analysis could attempt to balance system parameters, including vehicle performance, train control systems, operating patterns, and vehicle design, for all the vehicles operated at a given time to develop a safe and effective system.

Results of this type of risk analysis could be used to develop HSR vehicle design parameters tailored to the specific operating scenario. For example, HSR vehicles might have 'x' crashworthiness if they were operated in shared-use situations only with commuter rail vehicles of type 'z' and 'y' crashworthiness if they were operated with freight cars. All system parameters could be considered in an attempt to identify the optimum possible without compromising safety.

Balancing system elements also recognizes that making rail vehicles stronger to sustain collision forces (collision protection) usually creates a heavier vehicle that requires more braking effort to stop in the same distance as a lighter vehicle, thereby sacrificing performance (collision avoidance).⁷⁷

The objective of this research is to identify infrastructure and operating strategies that can improve the operation of shared-use HSR systems; therefore, rolling stock has not been directly considered. Because U.S. crashworthiness standards clearly reduce the options for planning HSR systems, additional research is needed to resolve this conflict.

TRACK-SHARING BENEFITS

Given the great advantages of dedicated high-speed systems and the problems with shared-use HSR systems, why develop a shared-use system? As noted earlier, shared-use usually is adopted to overcome feasibility problems such as high cost and political opposition to dedicated lines.

By allowing an initial HSR system to be developed, shared-use opens the door to future improvements once the benefits of the system are recognized. Incremental improvements, such as segments of new dedicated HSR tracks, can be added to shared-use systems to increase system speed and frequency. Such incremental improvement programs are common in Europe. The initial shared-use HSR system must have the integrity to illustrate the benefits of the HSR system—nothing would be worse than a “starter line” so limited as to discredit the idea of HSR.⁷⁸

Shared-use also allows HSR systems to take advantage of accessibility to center cities and feeder networks provided by existing rail lines. Although shared-use is not optimum, it is an important tool for constructing and operating HSR systems. Four significant benefits of track sharing by HSR are outlined below.

Lower Cost

Cost is the main reason for adopting a shared-use approach to high-speed rail. Dedicated high-speed tracks can cost up to \$50 million per route mile to build. In some corridors, the less expensive options—upgraded existing railroads with maximum speeds of 90 to 150 mph (144 to 240 km/h)—can provide affordable travel improvements that expand the range of transportation choices.⁷⁹

In partial shared-use high-speed rail systems, the extremely high cost of constructing dedicated lines in particular locations drives the decision to adopt shared-use operations. Examples include areas near cities where the land is very expensive and locations that would require construction of expensive structures, such as tunnels, bridges, and urban subways.

In the initial high-speed rail planning process, a cost-benefit analysis should be done to determine if sections of dedicated line are more cost effective than total shared-use. Although total shared-use systems are generally less expensive than dedicated systems, a Canadian study of high-speed rail on the Quebec–Windsor corridor found that dedicated segments were less expensive than total shared-use segments in some locations. This finding was highly dependent on local conditions (the availability of an alternative right-of-way through agricultural land that would need fewer grade separations and utility relocations), but it is a good reminder to investigate all costs in the planning process.⁸⁰

Reduced Impacts

A second reason for building shared-use high-speed rail systems is to reduce the social, political, economic, and environmental impacts of the project. In some cases, the impacts of providing the line may be higher than the benefits. For example, the environmental impacts of constructing a dedicated route through a wetland or neighborhood may be too high to warrant construction. In many cases these impacts can be mitigated, but the mitigation costs can be so high that shared-use is optimal. When impacts cannot be mitigated, for example if building a dedicated route through a certain area is infeasible for political reasons, adopting shared-use enables the project to be built.

Increased Accessibility

A third reason for building a shared-use system is accessibility. Sharing tracks can enable high-speed trains to get to locations that they could not otherwise reach. The best example is providing access to rail stations located in the heart of cities that are nodes for transportation systems.⁸¹ This is common in European shared-use high-speed railroads. In many cases, building a dedicated high-speed rail line to these locations would be extremely expensive and would have impacts that could not be mitigated easily.

Provides Network Benefits

A fourth reason for building a shared-use system is that shared-use can provide the high-speed system with network benefits. Network benefits are similar to accessibility, but can be thought of as at the other end of the trip—in other words, as a type of “feeder” system. In this case, high-speed trains operate over the regular rail network like any other intercity train and provide passengers with nontransfer service on the high-speed line. When high-speed trains share tracks with other trains, the high-speed network can be vastly expanded over what would be possible when all new lines needed to be constructed. This takes advantage of a large network to attract passengers and revenue to the high-speed system and can help build demand for a dedicated high-speed line. A good example is France’s TGV Mediterranean Line: The portion south of Lyon was originally served by TGV trains operating on shared track, but a dedicated line was built to serve the customers attracted, in part, by the original shared-use segment.

CHAPTER 4. PLANNING STRATEGIES

This chapter presents recommendations for planning shared-use HSR systems. Planning is especially important for shared-use high-speed rail systems because they are complex, involve many stakeholders, are expensive, and can have a large impact on a nation's transportation network. The importance of planning may seem obvious, but many transportation projects have suffered the consequences of poor planning: higher costs, longer construction time, lower-quality operations, increased impacts, or a combination of these problems.

OVERVIEW

This chapter focuses on planning issues of particular importance for shared-use HSR systems; it does not describe the general railroad improvement planning process. Many good references on railroad improvement planning are available, including a technical working paper from the FRA, U.S. DOT, (*Railroad Corridor Transportation Plans, A Guidance Manual*)⁸² and Chapter 17 of the American Railway Engineering and Maintenance-of-Way Association's (AREMA) *Manual for Railway Engineering*.⁸³ Those references provide a step-by-step process for corridor evaluation and preparation of improvement plans.

Other good sources of information on railroad corridor planning are the improvement plans cited in Chapter 2. Reviewing these plans provides insight into the overall planning process.

IMPORTANCE OF PLANNING

Comprehensive planning is important for all types of infrastructure systems, but the following are five reasons that it is especially critical when developing shared-use high-speed rail systems.

Safety—One of the most important differences between moving people and freight concerns system safety: An accident involving a passenger train is generally more serious than one with only freight trains, and freight railroad owners are extremely concerned with liability issues if passenger trains operate on their infrastructure.⁸⁴ Therefore, shared-use high-speed rail planning must focus strongly on safety, specifically on preventing accidents and minimizing their impact. Accidents may be more likely the result of the shared-use infrastructure (that is, poorly maintained tracks) or other trains operating on the system rather than the new HSR system trains.⁸⁵ Thus, safety must be considered for the entire shared-use system, not just for the HSR system.

Large Number of Stakeholders—As outlined in Chapter 3, one key difference between shared-use HSR system planning and typical railroad planning is the large number of stakeholders involved.⁸⁶ There is significant literature on how different organizations can work together in the

planning process; therefore, these topics are not covered in this research. This research simply makes the point that when developing a plan for shared-use HSR systems, it is critical to think carefully about the planning process and the needs of all stakeholders. These elements are especially important because sharing tracks with other users may be a new experience for many railroad infrastructure owners, public or private.

Understanding Rail System Capacity—One key difficulty faced when considering new passenger rail service is the perception by nonprofessionals that there is a great deal of excess capacity on the existing railroad system. When people see a railroad track with a train every hour, they may think that there are 59 minutes left to operate new passenger trains. Determining the actual capacity of a rail line is far more complex than what one sees at a single point, so comprehensive planning is necessary to evaluate changes to rail system operations.⁸⁷ There may be available capacity that is not obvious; for example, capacity may be freed on one line by shifting some traffic to another vaguely parallel line.

Highly Interrelated Infrastructure—One complex problem with planning railroad infrastructure is that rail networks are highly interrelated. An infrastructure improvement in one location can have significant impacts in another location, sometimes quite a distance from the improvement. Compounding this problem, changes to operations or scheduling can also have wide-ranging impacts. These impacts take place on a critical element in a nation's transportation infrastructure—disruptions to the railroad network can have significant economic impacts. Because of this network nature, railroad planning must be completed in a comprehensive, methodical manner.

High Cost of Rail Infrastructure—Improving a railroad is expensive—not only the basic infrastructure, but also the costs of taking a line out of service during construction, additional right-of-way needed for improvements such as adding a new track, and addressing the complexity of the interrelated nature of railroad systems. A poorly planned improvement will increase operating costs and problems for the railroad; improvements must be carefully planned to avoid wasting time and money and avoid creating problems in operating the finished railroad.

HIGH-SPEED RAIL SYSTEM PLANNING

Planning is critical to the development of a successful shared-use high-speed rail system. This research considers how the planning process views the question of dedicated versus shared-use infrastructure and how planning is used to identify and evaluate capital and operating strategies for improving shared-use high-speed rail systems. This section provides a brief description of planning process issues especially relevant to shared-use high-speed rail systems.

Market Analysis

The first step in the HSR planning process is estimating how many people would use the new service. This estimate is based on such input variables as demographic data (for example, population and socioeconomic characteristics), economic data, and transportation data (for example, characteristics of travel by all the modes serving the particular market—car, plane, rail).

The main objective of the market analysis is to define the level of HSR service needed to attract a significant share of the given travel market. In its most basic form, this definition will be something like, “In order to attract enough customers to make high-speed service a reasonable investment, the service must offer trip times of less than ‘x’ hours, operate ‘y’ times per day, and cost ‘z’ dollars.” The travel time, frequency, and cost estimates derived from the market analysis then are used to develop the system’s infrastructure and operating plan.

Most transportation systems fit a certain market niche. High-speed rail is best for trips that take too long to drive but are too short to fly, given the large amount of time needed for airport access. This market is assumed to be trips that the high-speed system can make in less than 3 hours. Therefore, the HSR market will depend on the system’s average schedule speed, which is based on the system’s maximum speed and operating pattern.

Frequency is also important in determining market demand. For example, if customers have a choice between flying (4-hour total travel time) with flights operating every hour versus taking HSR (3-hour total travel time) operating twice a day, many will fly. Airlines have recognized the importance of frequency and are using small regional jets to increase frequency economically in smaller markets. Many European railroads schedule service hourly or better, between major cities. This is probably the level necessary to provide attractive service.

The other side of the frequency issue—congestion—is of concern to transportation companies. It is difficult to expand airline passenger capacity without overloading airports, but an HSR system can easily increase the train length to serve more passengers without significantly impacting rail system capacity.

Infrastructure and Operating Plan

Market analysis provides planners with the travel time and frequency requirements needed to create a successful high-speed rail system. Planners use these requirements to determine the infrastructure and operating plan for the HSR system.

The first choice to be made is between a dedicated-track HSR system and a shared-use system. The choice depends on the travel market identified in the market analysis, since there is an effective maximum speed for each type of system. If the market consists of two cities that are far

apart, the travel time requirement might call for a dedicated line; moderate distances could be served by partial shared-use lines; short distances could be served by totally shared-use lines. The same type of analysis holds true for frequency—higher frequencies are more likely to require dedicated lines or additional tracks.

Generally, the track type is chosen to keep the travel time below 3 hours. Amtrak’s Acela Express service uses a totally shared-use system on the busy Northeast Corridor to make the 150-mile trip between New York and Washington in 2 hours, 45 minutes.⁸⁸ To meet this travel time objective, the NEC’s infrastructure was designed to provide sufficient capacity and to allow speeds up to 150 mph. In contrast, California is planning a partially shared-use line that will enable express trains to travel the approximately 380 miles between San Francisco and Los Angeles in approximately 2-1/2 hours; the dedicated segments will be designed for approximately 200-mph service, and the shared-use segments will have significant capacity and speed improvements.

If a shared-use approach is chosen, the existing railroad infrastructure must be analyzed to determine what improvements are needed to enable the high-speed system to meet its travel time and frequency objectives. This analysis must consider both the trains currently operating on the shared-use segments and expected growth, and it should identify a variety of capacity and speed improvements for the planned line. The ultimate improvement program should be determined through an iterative planning process that evaluates different combinations of infrastructure and operating strategies.

Economic Analysis

The final step in the shared-use high-speed rail planning process is completing an economic analysis to determine if the benefits of the system outweigh its costs. An HSR system provides many external benefits beyond strict economics, including reducing congestion at airports and on highways and reducing energy use.⁸⁹ As one interviewee put it, “High-speed rail is not cheap, but a well-planned system can be cheaper than the alternatives.”⁹⁰

After completion of the economic analysis, the decision-makers can determine whether to construct the high-speed line. Results of this analysis often are used to refine the proposed HSR plan. If the costs are too high, planners can return to the infrastructure planning step and evaluate the effectiveness of lower-cost systems, such as systems that use more shared track.

RECOMMENDED PLANNING STRATEGIES

This section makes the following recommendations for planning shared-use HSR systems:

- Understand project objectives
- Consider a range of improvements

-
- Consider improvements for other operators
 - Maximize use of simulation
 - Prepare a prioritized infrastructure improvement program
 - Consider funding in system planning and design
 - Plan for maintenance
 - Preserve rights-of-way

These recommendations are outlined in more detail below.

Understand Project Objectives: Travel Time and Reliability

The name “high-speed rail” may mislead people into thinking that high maximum speed is the objective, but customers care about total travel time, not maximum speed. Although this sounds simple, there are examples of transportation systems designed around this misunderstanding.⁹¹ Raising top speeds in a corridor may be only one of many ways to reduce trip times, but it may not be the most cost-effective way.⁹²

The customer travel time objective is significant in shared-use HSR systems because a major reason for adopting shared-use is to provide customers more direct service, therefore shortening travel times. Two examples are sharing tracks to provide direct access into a city center (accessibility) and sharing tracks to increase the catchment area for high-speed trains (network benefits). One benefit of track sharing in these examples is that passengers do not have to change trains to reach their ultimate location. A significant body of research shows that passengers would rather not transfer, and transfers reduce patronage up to 35 to 50 percent, depending on the situation. Therefore, shared-use can attract passengers by providing more convenient service.

Closely related to the travel time objective is reliability. Customers want travel systems that reliably get them to their destinations on time.⁹³ To succeed financially, HSR systems are counting on passengers paying a premium for fast and reliable service.⁹⁴

One way to improve reliability is to consider it explicitly during system planning.⁹⁵ This might include examining potential operating problems and planning infrastructure that addresses those problems before they occur, instead of planning a bare-bones system. Examples include providing additional tracks that can serve as convenient waiting areas around important interlockings or terminals.⁹⁶ It is best to overdesign facilities to increase system reliability, for example, building passing tracks longer than the calculated minimum to provide a cushion for delayed trains.

Another way to improve reliability is to specify high-quality equipment and construction. This may seem to contradict conventional wisdom to minimize costs, but because shared-use HSR

infrastructure is used intensively, it needs to be designed to maximize attributes such as capacity and speed rather than to minimize costs.⁹⁷ The same is true of rolling stock. High-speed service should not be delayed by such problems as broken-down commuter rail equipment because the customer does not care who caused the delay. An important institutional issue is to determine who is responsible for ensuring that the failure of a train by one operator does not ruin all the services operated on the line.⁹⁸ Amtrak's Acela express trains are a good example—their specifications require very high reliability.

The HSR planning process involves a constant balancing of different improvements against each other to identify the optimal investment plan. Keeping the project purpose in mind assists planners in this process. For example, consider the question of whether to improve capacity or increase speed on a given segment of shared-use line. The answer to this question depends on how these improvements would reduce travel time and increase reliability, based on such variables as the location, length, and purpose of the shared-use segment.

A specific situation might be where short sections of shared track provide access to city-center stations. Here high-speed rail trains will be going slowly (since they need to stop or are just starting), so capacity improvements that provide greater reliability might be more valuable than speed improvements. On short segments in the middle of a route, speed improvements that reduce total travel time by providing a more uniform operating speed might be more valuable than a capacity improvement.

Consider a Range of Improvements

Ways to improve operation of a shared-use high-speed rail system fall into three major categories: infrastructure, rolling stock, and operations solutions. Improvements in each category should be evaluated against improvements in other categories to develop the optimal improvement plan.

A good example of a structured approach to trading off different types of improvements is the Swiss National Railroad's (SBB) Integrated Product Planning Process.⁹⁹ The SBB views this process as a Planning Triangle (see Figure 5) with three elements at the corners: Products, Rolling Stock, and Infrastructure. Products are the services and schedules operated (for example, commuter rail, intercity rail, freight); rolling stock means the type of rolling stock used to provide a particular service; and infrastructure consists of the physical system (tracks, signal systems, stations, and so on). SBB planners use iterative techniques to evaluate changes in each of these elements to optimize the system as a whole. This triangular view effectively communicates the relationship between the three elements and their ability to meet market demand.

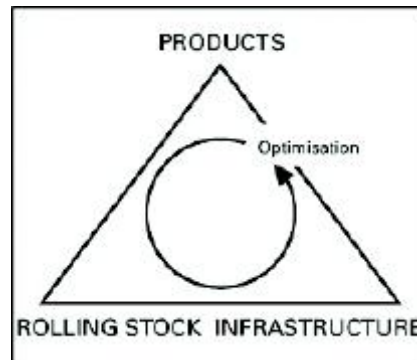


Figure 5. SBB Planning Triangle

In one example of applying this process, the SBB decided to use tilting trains to provide higher-speed service (a rolling stock solution) rather than fully rebuilding tracks (an infrastructure solution) because the former is more cost effective. This planning process also led to the decision to make a large infrastructure investment in the Zurich-to-Bern corridor to provide the product that market required—frequent service throughout the day with travel time of less than 1 hour.¹⁰⁰

One critical aspect of considering a range of solutions is that often railroads are not oriented toward thinking creatively. Many railroad engineering staff members are responsible for the challenging task of keeping the existing railroad in operation on a day-to-day basis and lack the time to think of new solutions. Switzerland has organized a separate group (Extended Processes or XP) to develop new approaches and implement new projects. A good example of this type of thinking is the use of new technology to obtain a specific goal rather than to replicate old processes.¹⁰¹

In summary, operations (schedule), rolling stock, and infrastructure must be evaluated together to identify the most cost-effective and efficient solutions for improving shared-use high-speed rail systems. In some cases, a rolling stock solution is most effective; in others, adjusting operations is optimum. Planners must keep an open mind to different solutions.

Consider Improvements for Other Operators

Not only should planners consider improvements to system elements other than infrastructure, they also should consider improvements to the operation of another shared-use system operator. It can be more advantageous for the high-speed service to make improvements that directly benefit other operators than an improvement specifically for the HSR service.

The best examples of this strategy involve improving another operator's rolling stock to achieve additional capacity and higher speeds. A good example is replacing a commuter rail operator's

locomotives with improved diesel or electric locomotives that provide better acceleration and deceleration—a huge benefit for commuter trains that stop every few miles. Another example is installing cab signaling or other train control equipment in other operators' locomotives to increase maximum allowable speeds.¹⁰²

These examples highlight the importance of the planning process, where ideas like replacing diesel commuter trains with electric can be traded off against infrastructure improvements needed to increase capacity. They also show the need for building strong relationships between all system users, which will help the operators work together to find optimal solutions for improving shared-use system operations.

Maximize Use of Simulation

The wide range of possible improvements (operating, rolling stock, and infrastructure—both for the high-speed system and other operators), combined with the complexity and interrelatedness of railroad infrastructure, demands careful, detailed planning for shared-use high-speed rail systems.¹⁰³ Most of those interviewed for this research recommended completing as much computerized simulation modeling as possible before starting a railroad improvement program. As one interviewee put it, the more modeling done up front, the less expensive the overall project is likely to be because you can refine the plan to its most essential elements.¹⁰⁴

Simulation programs provide many benefits to the planning process. They enable planners to identify impacts well away from where improvements are being made, which is especially necessary given the interrelated nature of railroad systems. Simulations also encourage creative problem solving because after they are calibrated, they can easily estimate the benefits, impacts, and costs of different improvement packages. To analyze several improvement packages by hand would be prohibitively time consuming.

There are many types of simulation programs, and generally one is good at one stage of the process to answer certain questions, while another will be required at a different stage.¹⁰⁵ An important component of railroad planning is knowing what computer simulation tool to use in what situation.

Although simulation models are a key part of the rail system planning process, they have limitations and must be used with care. They must be validated to actual conditions before use, they seldom model yard operations, they generally ignore resource constraints such as crews, and their simplifying assumptions generally create an inherent optimism about overall congestion, schedule adherence, and recoverability.¹⁰⁶ There is no substitute for knowledge from experienced railroad planners and application of good planning principles.

After the planning process, the HSR system needs to use simulation continuously to develop improvement plans and in its day-to-day tactical planning. As outlined in Chapter 7, simulation

programs can be developed to assist dispatchers in addressing service disruptions and unexpected events.

Develop a Prioritized Infrastructure Improvement Program

The goal of the planning process is to identify the most effective set of improvements necessary to provide the service demanded by the market. There are many ways to save 30 seconds in travel time, but planners must identify how to do it with the least economic, political, technical, and environmental cost.¹⁰⁷

The shared-use HSR system infrastructure plan should clearly identify infrastructure priorities and set forth a realistic implementation plan.¹⁰⁸ This sounds like common sense, but making changes to an existing infrastructure system, such as improving a railroad, often requires incrementally improving the system rather than one-time programs; therefore, the need for a prioritized infrastructure plan before work begins needs to be emphasized. Without a detailed long-range plan, it is difficult to know if the short-range plans and projects will address anything other than immediate problems. Short-term solutions may make the long-term problems worse and ultimately have to be removed and replaced—an expensive learning experience.¹⁰⁹

Development of a comprehensive infrastructure investment program is critical when improving existing infrastructure systems because the railroad network must continue to operate while the improvements are being made. Good planning can reduce the impact of construction on existing train service¹¹⁰ and makes construction more efficient and cost effective. Piecemeal planning can impact railroad operations needlessly while providing unnecessary improvements in some places and not providing needed improvements in other places.

Developing a prioritized investment program requires strong technical analysis (especially simulation), creative thinking about applying many different strategies to the problems, and the ability to bring the different stakeholders into agreement.

Consider Funding in System Planning and Design

The source of construction and operating funding should be considered when planning shared-use HSR systems.¹¹¹ This is particularly important for large transportation infrastructure systems such as railroads, which have a natural tradeoff between capital and operating costs. One can build a robust system that minimizes operating costs, or a bare minimum system with higher operating costs. If it is easier to attract capital for the initial investment than for ongoing maintenance costs, the best solution is to build the more robust system and vice versa. The important point is to consider the availability of capital and operating funding in the design process.

Many shared-use HSR plans recommend an incremental approach to upgrading the system. This is a good example of considering system funding in the planning process because it recognizes budget limitations and proposes a long-term program of capital improvements (as funding becomes available), coupled with improvements to service (lower travel times and increased trains). In these plans, the incremental improvements to service are based on operating a reliable service rather than stretching resources to provide faster, but less reliable, service.¹¹²

Plan for Maintenance

Track and rolling stock maintenance is critical for safe, reliable operation of all railways, especially high-speed systems. Degraded track can cause safety problems (such as derailments) and significantly reduce service quality. The FRA recommends that strict maintenance procedures be followed for high-speed systems, including more frequent track and vehicle inspection, to reduce the frequency of accidents caused by maintenance problems.¹¹³

Maintenance is a serious problem for railroads: It not only costs money but also costs capacity because tracks cannot be used while they are being maintained or improved. The impact of maintenance on capacity is especially critical in shared-use HSR systems because a key shared-use strategy is to operate freight trains at night when high-speed trains are not running. Unfortunately, most track maintenance is done at night, which creates a conflict between freight movements and maintenance. If freight trains cannot be restricted to night operations, additional infrastructure will be needed to provide capacity for operating freight trains during the day. Since freight trains have different operating characteristics from high-speed trains, providing this additional capacity can be expensive.

A shared-use HSR system's increased need for maintenance ripples through the system. It means more facilities for maintenance workers, more maintenance yards, more equipment, and so on.¹¹⁴ Recommendations that should be considered for improving maintenance in the planning process include the following:

- **Infrastructure**—Most of those interviewed for this research recommended building a higher-quality infrastructure for shared-use HSR systems, including installing more reliable equipment. Other infrastructure planning strategies include providing sufficient space to enable track maintenance equipment to operate efficiently and building additional track maintenance facilities. Implementing a significant preventative maintenance program can minimize the need for major infrastructure replacement projects or emergency repairs.
- **Maintenance Equipment**—Another important strategy is to build maintenance equipment that minimizes capacity impacts on the system. On the Northeast Corridor, Amtrak has maintenance equipment that can travel to worksites under the same operating rules as freight trains and can be set up or taken down quickly to minimize its impact on capacity.¹¹⁵

- **Operations**—Maintenance staff must be well trained to maximize their efficiency and to remain safe while working in the high-speed rail environment.
- **Rolling Stock**—Rolling stock from all operators sharing the HSR line must be well maintained. Improperly maintained trains can have a disproportionate effect on track quality, compounding operating costs and problems.¹¹⁶

Preserve Rights-of-Way

The planning horizon for shared-use high-speed rail systems will generally be long, and upgrades often are implemented incrementally over many years. Unlike advance planning for future highways, there is little, if any, planning for high-speed rail systems.¹¹⁷ Therefore, a key product of early high-speed rail planning efforts should be right-of-way preservation plans that can provide the land necessary for future capacity improvements (for example, additional passing tracks at stations), additional support facilities (for example, maintenance depots), and alternative rights-of-way for dedicated segments.¹¹⁸

This should be considered early in the process because after high-speed rail service is started, adjoining land usually is developed to take advantage of the new transportation system.

CHAPTER 5. INFRASTRUCTURE IMPROVEMENT STRATEGIES

This chapter outlines infrastructure strategies recommended for improving the operation of shared-use high-speed rail systems. Infrastructure is defined as track, structures, stations, and grade crossings. Signal systems can be considered part of the infrastructure system, but they are described separately in Chapter 6.

Most of the improvement strategies described in this chapter are well-known and are similar to those used to increase capacity and speed on any rail system, so they are not described in detail here. This chapter describes infrastructure considerations particular to shared-use high-speed rail systems. The planning process outlined in Chapter 4 should be used to develop a prioritized program specifying the type, location, and extent of improvements needed to optimize the shared-use high-speed rail system's operation.

The best way to summarize the recommendations of interviewees for this research is, “There is no substitute for infrastructure in shared-use high-speed systems.”

TRACK IMPROVEMENTS TO INCREASE CAPACITY

Capacity follows safety as the most critical concern for shared-use high-speed rail systems.¹¹⁹ In evaluating a railroad's capacity, it is necessary to remember that capacity is affected by random events such as accidents, train problems such as breakdowns, and the weather, in addition to the actual scheduled train service.¹²⁰

Often the locations where shared-use is most desired—for example, providing access to center city stations—are the locations with the most critical capacity problems. Rail infrastructure owners will insist that any proposal to operate other trains on their lines include improvement programs to eliminate capacity problems.

The capacity of a railroad depends on the number of tracks available, but capacity increases nonlinearly as additional tracks are added to the system because the additional tracks allow for more track specialization. For example, a one-track line has a relatively low bidirectional capacity. Adding a second track increases capacity by more than 100 percent because each track serves traffic in a single direction. Adding a third track to allow trains to overtake trains moving in the same direction further increases capacity, and adding a fourth track to give trains in both directions their own track to overtake trains increases capacity still further.¹²¹

The simplest way to add capacity is to construct additional tracks. This section describes three types of additional tracks: mainline, passing, and dedicated. The following section focuses on

track improvements that increase speed, but many of the recommended track improvements increase both speed and capacity.

Add Mainline Tracks and Universal Crossovers

Modeling results have shown that a shared-use HSR system can operate on a single-track railroad with passing sidings, but predict that this would lead to delays and significant reliability problems.¹²² Even at low service levels, single-track lines require significant infrastructure improvements.¹²³ Therefore, to operate frequent and reliable HSR service on shared-use lines, it is recommended that lines have a minimum of two mainline tracks connected by high-speed universal crossovers that enable high-speed trains to overtake slower trains. In the words of one operator, to increase capacity there is no substitute for multiple tracks.¹²⁴

An important part of HSR planning analysis will be determining if more than two mainline tracks are needed. For example, to enable Caltrain (the San Francisco Peninsula's commuter rail service) to increase its service as planned, a detailed operational analysis has shown that it will eventually need a primarily four-track rail line with a few short segments of two-track line.¹²⁵

Add Passing Tracks

A two-mainline-track railroad with high-speed universal crossovers allows high-speed trains to pass slower trains going in the same direction by switching to the second track for the passing maneuver. However, this can use a significant amount of the second track's capacity, especially when a high-speed train needs to pass another relatively fast train, such as a commuter train. Also, using the second track for passing may be impossible on lines with frequent train service in both directions. Therefore, a third mainline track (or additional passing track) is often needed to allow high-speed trains to overtake other trains in shared-use HSR systems.

Where to locate passing tracks is a key question when planning additional tracks. Since their purpose is to allow faster trains to pass slower trains, passing tracks are needed only where passing is necessary, which depends on the train schedule. There are two strategies for determining the location of passing tracks. One is to start with a proposed train schedule, use simulation to determine where passing is needed, then build the passing tracks in these locations. The alternative is to build the passing tracks where they can be constructed most easily, then create a schedule that fits the infrastructure. Often the solution is a combination of these two strategies.

The minimum length of passing track depends on the difference in speed between the two trains—the smaller the difference in train speed, the longer the length of passing track needed. Schedule reliability must also be considered. Because the location of passing tracks is based on the schedule, the passing tracks will not be in the right locations if the trains are not on schedule. Therefore, passing tracks should be longer than the minimum length to allow for train delays and

provide more flexibility for the system. In addition, freight trains in the United States can be very long, so long passing tracks allows those trains to use the passing tracks.

Constructing passing tracks through stations allows high-speed trains to overtake slower trains when the slower trains are stopped in the station. This is a common practice on existing shared-use lines. Building long segments of passing tracks through several stations improves capacity and reliability because overtakes can take place anywhere on the segment. Building passing tracks for HSR through low-volume stations (those not served by HSR) well away from platforms can enhance safety for waiting passengers. Figure 6 illustrates additional tracks through stations.

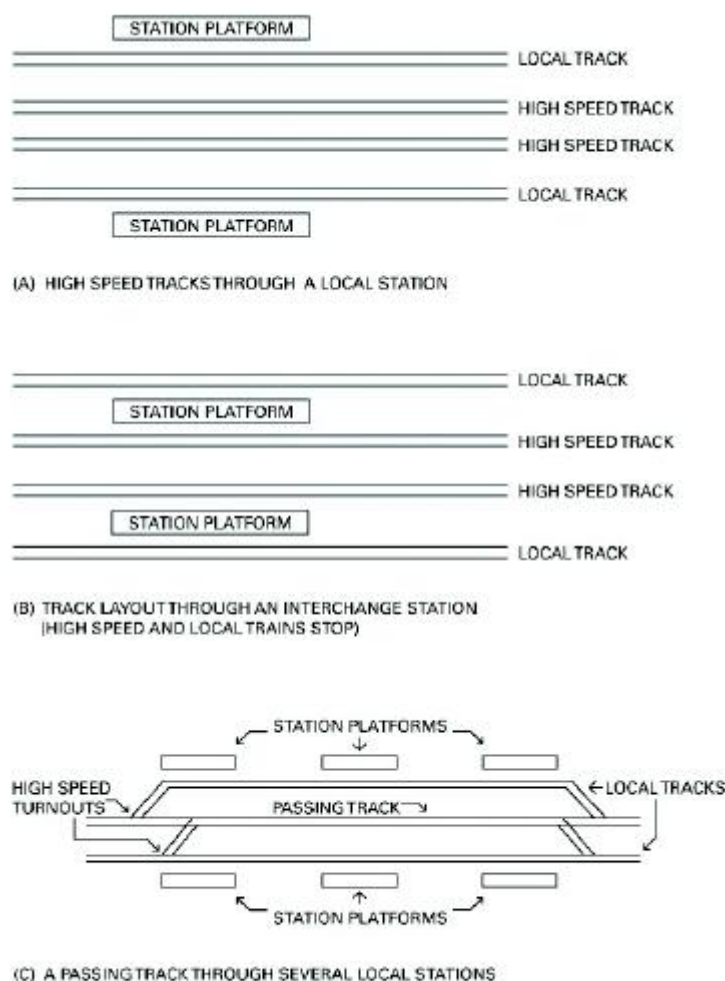


Figure 6. Schematic Illustrations of Additional Track

Build Dedicated High-Speed Segments

The ultimate in passing track is a long segment of additional mainline track. Therefore, a common pattern on high-frequency lines (such as the New York City subway) is four tracks, with slow trains using the outside tracks and fast trains using the inside tracks. On some routes in Great Britain where a four-track infrastructure is in place, once a train is switched to the fast tracks it does not stop at intermediate stations, so the line can be operated at close to maximum theoretical capacity.¹²⁶

The ultimate capacity improvement for a high-speed rail system is to build dedicated high-speed segments (these also allow operation at the highest possible speeds). Therefore, shared-use high-speed rail systems should build as much dedicated high-speed track as possible.¹²⁷ Another way to obtain a dedicated high-speed segment is to construct a new route for the other original segment users. This could provide improvements for the other operators and create a win-win situation. A good example might be building dedicated track for freight trains to bypass stations. This strategy has been used often near freight marshalling yards¹²⁸ and on steep grades.¹²⁹

Constructing dedicated high-speed segments is the general approach used by European HSR train operators to obtain speed and capacity improvements. France's TGV system uses shared track in very limited situations, primarily for entering cities and as extensions to the network. Once the TGV trains are outside major cities, they operate on dedicated track. Germany is also building dedicated ICE lines in parallel with regular tracks on major routes.

TRACK IMPROVEMENTS TO INCREASE AVERAGE SPEED

This section describes six infrastructure improvements that can increase speed on shared-use high-speed rail systems. As mentioned above, some of these improvements will also increase capacity.

When reviewing speed improvement strategies, one should consider the importance of uniform speeds on a rail line. Train acceleration and deceleration caused by changing speed limits can waste significant amounts of time and energy. Train speed limits should be relatively uniform to minimize travel time and energy use. This generally means that bringing a slow segment of track up to the same speed as neighboring segments provides a greater benefit than increasing the top speeds in segments with high maximum speeds. Many of the strategies described below are best applied where they can improve speed on a particular segment to make the line speed more uniform.

Improve Track Structure

Track quality is a major factor in determining a train's maximum speed and has a significant impact on safety. Operating at high speeds on poor track could cause derailments or other accidents. Physical demand on track increases sharply with speed, requiring a stronger and more resilient track structure.

Federal Railroad Administration, U.S. DOT, regulations separate track into nine classes, based on various measures of track quality, including rail type (welded versus jointed), tolerances (for example, differences in gauge), and inspection frequency. For each track class, there is a maximum allowable speed.¹³⁰ The higher the track quality, the higher the allowable speed. Table 1 summarizes the track classes and maximum speeds.

Table 1: FRA Classes of Track and Maximum Operating Speed

Track Class	Maximum Passenger Train Speed, mph
1	15
2	30
3	60
4	80
5	90
6	110
7	125
8	160
9	200
Source: Code of Federal Regulations, Title 49, Part 213	

Most of the techniques for improving track quality are well understood by railroad planners. They include the following:

- Rebuild track substructure, improve drainage, replace ballast.
- Install concrete ties to reduce maintenance and improve track alignment control.
- Install elastomeric fasteners.
- Install continuously welded rail to reduce maintenance and improve ride quality.

- Consider the use of slab track for dedicated lines.¹³¹

For shared-use operations below about 120 mph, straightforward upgrading of existing track usually will suffice, generally including continuously welded rail (CWR). At higher speeds, additional improvements are needed, such as concrete ties and elastomeric fasteners.¹³² Figure 7 illustrates a new high-quality track constructed for the new German ICE tracks built between Cologne and Rhine/Main.



Figure 7. New German ICE Line Between Cologne–Rhine/Main
Source: DB AG/Warter

Another improvement to consider when making track improvements is fencing. It is especially important to keep people from crossing or walking along high-speed and high-frequency lines. Many European high-speed lines are fenced or otherwise protected from trespassers, sometimes with soundwalls. French TGV lines are equipped with intrusion detectors to alert operators of potential problems caused by objects falling from bridges or otherwise fouling tracks.¹³³

When plans are made to improve tracks, it is also critical to consider maintenance. One of the main problems with the Metroliner service in the Northeast Corridor was that planners underestimated the infrastructure requirements needed to economically sustain shared-use HSR operations. A premium track structure is required to operate high-quality high-speed service efficiently.¹³⁴

Reduce Horizontal Curvature

The second recommendation for improving speed is to reduce the line's horizontal curvature. Route curvature often is the principal constraint on average speed when existing trackage is used for high-speed rail service.¹³⁵ The three reasons trains must slow down on curves are safety, passenger comfort, and to reduce wear on rails. Five techniques for increasing speed in horizontal curves follow.

- **Mainline Changes**—Relocate mainline tracks to reduce horizontal curvature. This is often expensive and may not be feasible when right-of-way is unavailable. However, it can benefit both HSR and freight trains.
- **Superelevation**—Speeds on horizontal curves can be increased by superelevation, that is, raising the outside rail above the level of the inside rail. There are practical and regulatory limits to the amount of superelevation allowed: Excessive superelevation can cause significant rail wear on lines with heavy freight trains, and safety problems could occur if a train, especially a heavy freight, has to stop on a curve with excessive superelevation.
- **Spirals**—Spirals are the sections of track that transition from tangent (straight) track to curved tracks. Improving spirals enable trains to travel faster through a curve because the transition from straight track to curved track is more gradual. One of the first changes made to the Northeast Corridor before introduction of Metroliner service in the 1960s was to add spirals to the track, which previously had none.¹³⁶
- **Tilting Trains**—Passenger trains slow down on curves to maintain passenger comfort, so trains that tilt, essentially providing additional superelevation, help to increase the speed through curves. Among the railroads using tilting trains to increase speed through curves are Amtrak's Acela Express trains¹³⁷ and the Swiss National Railroad's new Intercity Trains.¹³⁸ Tilting technology is often a good alternative to extensive track work and right-of-way necessary to reduce horizontal curvature. Figure 8 illustrates the German ICE tilting train.
- **Dedicated High-Speed Rail Track**—This strategy consists of constructing a dedicated high-speed rail track through a curve with a superelevation appropriate for high speeds and allowing slower trains to continue using the existing track.¹³⁹



Figure 8. German ICE Tilting Train
Source: Deutsche Bahn AG Reduce Grades

The speed of high-speed trains is affected less by grade than by curvature, but grade is still an important concern, especially in shared-use high-speed rail systems. Most high-speed trainsets are lightweight and have a high power-to-weight ratio, so they can climb much steeper grades than heavy freight trains. Grades on dedicated high-speed rail lines such as France's TGV system (up to 5 percent in some locations) are typically much higher than those found on U.S. railroads (where most grades are less than 2 percent).

Because grades significantly impact freight train speed, they are an important concern for planning shared-use high-speed systems. If the high-speed system shares a route with freight trains, planners must carefully evaluate the impacts that slow-moving freight trains on grades will have on high-speed trains. The slow trains will reduce capacity and the grade could become a bottleneck on the route. This is especially problematic from the perspective of reliability. If a

high-speed train arrives while a slow freight is on the grade, the former will be delayed significantly.

There are two main infrastructure solutions for reducing the impacts of grade on shared-use high-speed rail systems:

- **Reduce Mainline Grades**—Reducing mainline grades generally requires large-scale construction projects, including building bridges, earthwork (cuts and fills), building tunnels, and other relatively expensive projects. These changes will help all trains that use a given section of line, but their high cost makes them difficult to implement.
- **Dedicated Track**—Building a dedicated track for the slow or fast trains in the area of the grade also can reduce the impact of grades on shared high-speed rail systems. When fast trains can overtake slow trains in the area of the grade, capacity impacts are reduced. A good example is the dedicated freight routes described above, but because high-speed trains can climb steeper grades, an alternative might be to build a more direct, but steeper, dedicated route for high-speed trains.

A non-infrastructure solution to the problem of slow trains on grades would be to add power to heavy trains. This could be done for the entire route, or helper locomotives could be added to heavy trains on the grades only.

Improve Structures

The speed at which a train can operate on structures such as bridges depends in part on the strength of the structure. Improving structures to increase maximum speeds can be a relatively low-cost strategy for reducing travel time.¹⁴⁰ One reason this strategy is effective is that structures with speed restrictions are a major cause of train acceleration and deceleration. Making speed limits more uniform by improving structures can create major travel time and energy benefits for all trains using the line.

Improve Turnouts

Turnouts are switches that enable trains to change from one track to another. Turnouts are designed for different speeds, both for trains continuing on the same track and for trains that are changing tracks. With respect to speed, turnouts are similar to structures in that they often have speed restrictions. Two important aspects of turnouts should be considered in planning a shared-use high-speed rail system:

- **Install Higher-Speed Turnouts**—Installing turnouts that enable faster speed increases average speed on a rail line and benefits all trains on the line. As one interviewee said, “When constructing a high-speed line, do not waste time with 30-mph turnouts.”¹⁴¹
- **Orient High-Speed Turnouts for High-Speed Service**—This means considering which route through the turnout will be used for high-speed trains and other trains on the line. In most cases the turnout should be oriented to enable the high-speed train to make the fast (straight) movement, but in special cases the faster route might better be used for non-high-speed trains.

Simplify Mainline and Station Track Network

Simplifying the track network means evaluating it and making changes to allow increased speeds (and capacity). Today’s passenger and freight trains are different from those that operated when older lines were laid out; therefore, the track layout may benefit from changes to better accommodate new types of trains and operating strategies.¹⁴² The simplest example is to remove turnouts when they are unnecessary, such as unused industrial sidings.

The area around passenger and freight terminals frequently can benefit from track simplification. These track networks often include turnouts and crossovers that once served an important purpose, but are now unnecessary or improperly located. There may be changes to track that could increase operating speeds and capacity in terminal areas. Because train speeds in terminals can be very slow, even small improvements can significantly improve travel time.

PASSENGER STATION IMPROVEMENTS

Passenger stations are an integral part of the high-speed rail system, providing a place for customers to wait for trains and make intermodal connections. They should be well designed, comfortable, safe, and attractive, but there are also some specific aspects of station design that must be considered in shared-use high-speed rail systems. This section describes design recommendations for shared-use high-speed rail stations: station safety, passenger access, and station tracks.

Increase Station Safety

The most critical concern for high-speed rail systems is safety. In addition to personal security, which is important for any public facility, railroad stations must be designed to prevent people from being injured by trains. This is especially important in a shared-use HSR system because the potential for injury increases when trains pass through stations at high speeds. Below are three recommendations of particular importance for increasing passenger safety at stations on shared-use HSR systems.

- **Provide Grade-Separated Platform Access**—People should never be allowed to cross railroad tracks at grade in any station with significant rail service. Stations should have grade-separated pedestrian ways with stairways, ramps, and elevators connecting them to the train platforms. All European high-speed rail stations and most other stations provide these features. A good technique for preventing people from crossing tracks (even when there is grade-separated access) is to build a fence between the tracks.
- **Consider Track Separation Systems**—Passenger stations on a high-speed rail line should have a means of preventing passengers from getting too close to the tracks. Trains passing through stations at speeds of 150 mph or higher produce airflows, along with the dust and debris that is being propelled, to a speed that could be a safety issue.¹⁴³ A track separation system similar to those used in some rapid transit stations (notably Paris’s Meteor Metro and London’s Jubilee lines) is shown in Figure 9. These systems generally consist of glass walls with doors that open when a train is in the station and stopped so that its doors are aligned with the doors on the station platform, much like elevator doors operate.



Figure 9. Passenger Separation System on Paris Meteor

Source: (c) RATP / Jean-François Mauboussin

Separating passengers from tracks is especially important in a shared-use high-speed rail system because there are stations where the high-speed trains do not stop. Trains traveling at

high speeds through stations can create turbulence that can throw waiting passengers off balance and could cause them to be injured by the train. (The FRA estimates that this could be a relatively frequent event.¹⁴⁴) Passenger separation systems also prevent passengers from attempting to board a train that is not stopping—an especially important feature for the visually impaired. Platform markings and audible/visual warning systems also could be used to keep passengers from getting too close to the platform edge.

- **Additional Station Tracks**—Another potential station safety improvement would be to construct station-through tracks (that is, tracks for trains that do not stop at the station) well away from the platforms. This would reduce the airflows experienced by waiting passengers. Gauntlet tracks could also accomplish this objective.

Improve Passenger Access to Trains

The second category of station recommendations for HSR systems addresses passenger access to trains. As this report has emphasized, all aspects of train operation should be considered in the planning process to reduce travel time. Train access improvements can be a fruitful area in which to look for time savings because with careful planning they can be inexpensive and effective.

For example, reducing dwell time at a station from 3 minutes to 1 minute saves 2 minutes. Repeating this process at several stations saves a significant amount of time, which can alleviate the need for more expensive time-saving measures such as track realignments. Five particular recommendations follow.

- **Provide Level Floor Boarding**—High-speed rail systems should adopt level floor boarding—that is, building high-level platforms or adopting low-floor vehicles—to speed passenger boarding and egress. Building high-level platforms may require construction of dedicated routes for freight trains around the station to prevent the platforms from interfering with large freight cars. Reducing boarding times for commuter trains sharing tracks with high-speed trains can increase capacity; this is another case where it may make sense for the high-speed operator to pay for changes to the commuter rail vehicles.
- **Improve Vehicle Access**—Although the vehicle is not a station infrastructure element, it must work with the station. Additional doors, wider doors, better-located baggage storage areas, and wider aisles on HSR vehicles can make passenger loading and unloading easier.
- **Increase Platform Space**—High-speed rail platforms should provide enough space for expected passengers and their baggage to wait and board trains efficiently without interference from exiting passengers.
- **Improve Platform Access**—Platforms should be designed with fast, efficient connections to the grade-separated platform access system. In the planning of Penn Station, it was found that passenger circulation is a constraint for track operations.¹⁴⁵

- **Improve Passenger Information**—The station should have clear, understandable information, available in all forms, directing passengers to the right platforms and trains. A good example is the new stations on France’s TGV Mediterranean line, which were designed to ensure that announcements on the public address system were easily understandable even when trains were passing through the stations.

Station Track

Two types of track improvements—passing tracks in stations and simplifying station tracks—were outlined above for stations. This section discusses a third type of track improvement, additional platform tracks.

Additional platform tracks enable passengers to transfer between trains at major stations. Facilitating passenger transfers means that the system can implement scheduling strategies that reduce capacity conflicts on the mainline tracks. (Chapter 7 outlines some of these scheduling strategies.) The Swiss and German passenger rail networks make extensive use of scheduled transfers.¹⁴⁶ To make these types of clockface headway systems work, node points (stations) should have as many tracks as possible.¹⁴⁷

GRADE CROSSINGS

Grade crossings are a significant safety problem for shared-use HSR systems. The increased frequency of trains often associated with a new service introduction could substantially increase accident rates at grade crossings. In addition, the risk to passengers and personnel, while small, does increase as speed increases.¹⁴⁸ These accidents impact both trains and road vehicles and can cause significant injuries to train passengers. Despite the FRA’s focus on rail safety and railroad efforts through Operation Lifesaver, there are still 10 grade-crossing accidents in the United States each day and more than 400 fatalities in 1998.¹⁴⁹

In Europe, there are no grade crossings on HSR lines and almost none on any moderately served railroad lines. Most grade crossings in Europe are protected by gates and fences that prevent vehicles from crossing the tracks once the gates are down, similar to four-quadrant gates in the United States. These gates are activated well before the train arrives and, therefore, can be down for several minutes. One reason the gates can be down so long is that most of the grade crossings are for small roads. However, even many small roads are grade separated, including private crossings for farm animals in agricultural areas.

In terms of grade crossings, the difference between the United States and Europe is striking. Most routes under consideration for shared-use HSR service in the United States have many grade crossings. A good example is the proposed California HSR system that would share tracks with

the existing Caltrain commuter rail service; that route has more than 40 grade crossings, some with very high volumes of traffic.¹⁵⁰

The FRA, U.S. DOT, has determined the following levels of grade crossing protection for U.S. high-speed rail systems:

- Over 125 mph—no grade crossings allowed.
- 110–125 mph—grade crossings with effective barrier device that can guarantee against intrusion of vehicles onto the track.
- Under 110 mph—grade crossings allowed with appropriate safety systems such as gates, signals, and so forth.¹⁵¹

The basic approaches to improving grade-crossing safety—closing grade crossings, replacing grade crossings with grade separations, and providing improved warning and enforcement devices—are outlined below.

Close Grade Crossings

The best strategy for improving grade-crossing safety is to close grade crossings. Although closing even the least-used grade crossings may meet with huge public outcry, it is critical to try to close as many grade crossings as possible.¹⁵² In the Illinois Incremental HSR Plan, the Department of Transportation undertook a major grassroots effort to close grade crossings. They worked closely with local school districts, ambulance companies, fire and police departments, city and county engineers, and elected officials to identify grade crossings that could be eliminated, finding that 28 percent of the total number could be consolidated into others.¹⁵³

New grade crossings should not be allowed on potential shared-use HSR routes.

Build Grade Separations

Another strategy for improving safety at grade crossings is to construct grade separations. However, these projects are often expensive and can be controversial with adjoining property owners.

Grade-separation projects are complex undertakings and must be planned carefully to reduce impacts on railroad operation during and after construction. It is critical to consider the long-term needs for the railroad and community when developing a grade-separation plan. Four particular recommendations for planning grade separation projects follow:

- Build grade separations that are large enough for the ultimate system, since they will be difficult and expensive to expand later.

-
- Attempt to combine grade-separation projects with grade-crossing closings; for example, build one grade separation and close two grade crossings.
 - Consider ways to combine grade-separation projects with other railroad improvements, such as constructing several grade separations together, to reduce costs and improve efficiency.
 - Consider future railroad and community improvements in grade-separation design; for example, make certain that the selected plan will allow efficient construction of a grade-separation project at an adjoining crossing in the future.

Developing a comprehensive grade-separation plan that is well integrated into the rail improvement program enables these projects to be implemented over time in a systematic and coordinated manner.¹⁵⁴

Improve Grade-Crossings and Warning Systems

Grade-crossings that cannot be eliminated or grade-separated should be subject to a significant planning effort to improve safety at the crossing. This means making roadway improvements to reduce the possibility of driving around closed gates and constructing fences along the tracks for the same purpose; working with other traffic control devices (for example, traffic signals to increase safety); and installing improved grade crossing warning devices, such as four-quadrant gates, constant time warning devices, and intrusion detection equipment.

Several advanced warning devices currently are in operation, including on the Northeast Corridor and on new light rail systems such as Los Angeles' Blue Line, which uses closed-circuit television enforcement. The Federal Railroad Administration, U.S. DOT¹⁵⁵ is researching these and many other ideas as part of its extensive program to improve grade-crossing safety.¹⁵⁶

CHAPTER 6. SIGNALING AND COMMUNICATIONS STRATEGIES

This chapter discusses signaling and communications system strategies for improving shared-use high-speed rail systems. It provides information to help readers understand the shared-use system recommendations but does not describe railroad signal systems fully. Many excellent books describe railroad signaling systems for the interested reader.¹⁵⁷

OVERVIEW

Signaling is fundamental to the safe, efficient operation of all railroads. Signal systems are critical in determining a rail segment's maximum speed and capacity because signals control the movement of trains. Railroad signaling systems have a long history and are continuously improved. A key safety concept is the fail-safe principle: designing railroad signal systems so that when they fail, they provide the most restrictive signal. For example, if a track circuit loses power, the signal indicator turns red; if no signal light is lit, the operator assumes the most restrictive signal indication for train operation.

In general terms, railroad signal systems provide the following three functions:¹⁵⁸

- **Block Signal Systems**—prevent trains from colliding on the same track
- **Interlocking Systems**—prevent trains from colliding when changing tracks
- **Control Systems**—route trains onto the best tracks for efficient railroad system operation

Signaling technology and systems have been developed to serve each of these functions at increasing levels of complexity. Certain block signaling systems are appropriate for single-track branch lines; more complex systems, such as cab signaling, are necessary for high-speed lines.

Shared-use high-speed rail systems require high-level signaling systems in all three functional areas to provide the safety, high capacity, flexibility, and reliability necessary to operate efficiently. The following sections outline each of the three basic signaling functions and describe signal system recommendations for shared-use HSR systems.

BLOCK SIGNAL SYSTEMS

Block signal systems are designed to tell trains to stop when there is danger of colliding with the back of another train. Because block signal systems must inform operators of the need to stop in enough time to stop the train, they are designed around train stopping distances. A train's stopping distance is based on factors such as the train's speed, braking ability, and weight, the weather, and the track gradient. The protected block trailing a train must be at least as great as the worst-case

stopping distance of the following train. As speeds increase, so do braking distances and thus block lengths, thereby reducing capacity. If several types of trains share the same tracks, the one with the worst braking performance must be used in the block system design.

Block signaling systems can be manual or automatic. Both systems inform the train operator that a given distance ahead of the train is unoccupied. In a manual system, this is done by people—today by radio; in the past with systems like handing the train operator a unique staff or token that conferred the right to occupy the track—and by machines in an automatic system. All railroads that might be considered for HSR service have automatic block signaling (ABS) systems in place, although some railroads still use manual systems on lightly traveled lines.

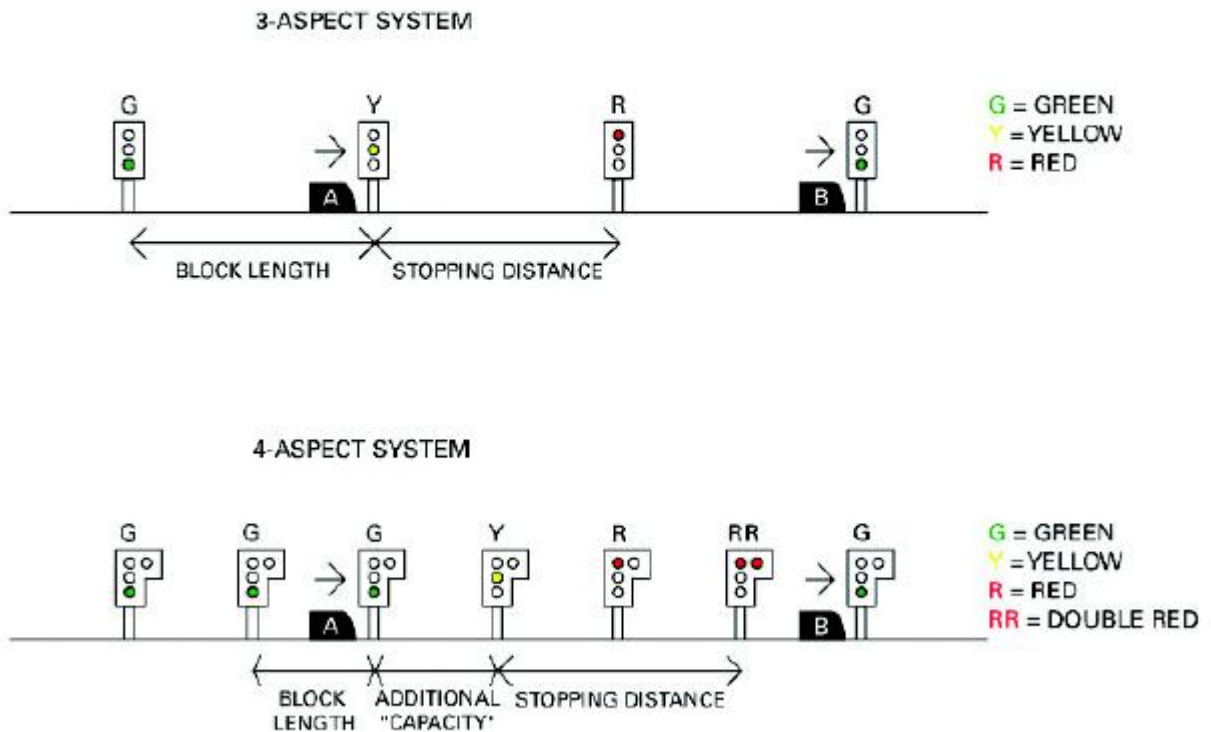
The basic element in an automatic block signaling system is the block, which is a segment of track controlled by one signal. The signal, located at the beginning of the block, generally is a set of colored lights mounted on a pole at the side of the track or on a gantry over the track. Much as a traffic signal informs motorists whether to proceed through an intersection or not, the railroad signal system, together with the railroad's operating rules, tells the operator what speed to operate at in the next block. These instructions are communicated to the train operator by the pattern of colored lights, called the aspect, on the signal. The system is called “automatic” because the presence of a rail vehicle on a block causes a short circuit in the signal current that circulates through the rails; this short circuit causes the signal system to display the proper aspects.

The simplest ABS system is based on three aspects: stop, approach, and clear. In a three-aspect system, the signal at the start of the occupied block indicates stop, the signal at the start of the preceding block shows approach (which means that the train can proceed but must be able to stop at the next signal), and the signal at the start of the next preceding block shows clear. A single green light is generally the clear aspect.

The main difference between a railway signal system and a roadway traffic signal is that because trains take a long distance to stop, the train operator must know well in advance that the signal ahead is stop. Block signaling systems use warning signals ahead of the signal displaying the stop aspect to tell the train operator to slow down; the number of warning signals depends on the number of blocks required to stop the train.

The block length (distance between signals) is based on the distance it takes to stop the train. The block length in a three-aspect system must be long enough to enable the train with the longest braking distance operating on the line to stop. Braking distance varies with the type of train, so different trains can operate at different maximum speeds on the line. Since high-speed passenger trains are lighter and have more relative braking power than freight trains, they can stop in less distance and, therefore, can operate at higher speed limits on the same section of track. For example, a typical Amtrak AEM-7 locomotive in the Northeast Corridor operating at a speed of 100 mph can stop in the same distance (about 6,000 feet) as a heavy freight train traveling at about 30 mph.¹⁵⁹

Block length is a critical factor in determining a rail line's capacity. All other things being equal, the longer the block length, the lower the capacity. This is because the "first" train could be anywhere within the first block, but in a three-aspect system the "following" train will always receive a cautionary "be prepared to stop" aspect a full block ahead of the first block. If the first train is at the end of the first block, the following train will slow down well before it needs to based on stopping distance. Shortening the blocks enables the system to locate trains more precisely and increases capacity. Figure 10 illustrates a block signaling system.



The ultimate reduction in block length would come from having blocks that provided exactly enough space for trains to stop. Because this distance changes based on train characteristics (such as speed, braking capacity, weight) and track conditions (such as grade, weather, horizontal curvature), no single distance works in all cases. A concept called “moving block” has been developed, which provides variable block lengths that move with trains on the system, thus keeping the trains spaced exactly far enough apart at all times to stop.¹⁶⁰ It is in operation on several rapid transit systems, but has not yet been applied on a mainline railroad.¹⁶¹

A major problem with shared-use high-speed rail systems is that the different train speeds greatly reduce the railroad line’s practical capacity.¹⁶² The main reason is that the signal system must be built for the lowest common denominator train, not specifically for high-speed trains.

BLOCK SIGNAL SYSTEM IMPROVEMENTS

Four types of block signal system improvements can be used to increase safety, capacity, and speed: adjust block length, add signal aspects, improve communications, and improve train control. To optimize the operation and safety of shared-use HSR systems, all four strategies generally need to be implemented. These signal system improvements are outlined below.

Adjust Block Length

Reconstructing the block signaling system to fit the needs of high-speed rail more precisely by calculating a new block length appropriate for high-speed service and relocating signals to meet this design increases capacity on a railroad line. This approach has two problems: It is likely to be expensive, and in shared-use systems, the signal system must still provide safe operation for the lowest common denominator train. Therefore, shortening the block length is not likely to be the best solution.

If the signal system is being significantly rebuilt for other reasons, such as modernization,¹⁶³ block length should be revised to better meet the needs of high-speed service.¹⁶⁴ It is worthwhile to prepare a detailed signal system analysis because improperly located signal positions or undesirable signal aspects, while overly safe, can add significant time to passenger train trips.¹⁶⁵ Revising signal spacing should be done with a view to providing a system that meets the needs of existing and future operations as efficiently as possible. Provisions should always be made for adding new technology and safety systems, and additional track infrastructure, in the future.

Add Aspects

The simplest way to improve a railroad line’s capacity is to add aspects to the block signal system. Adding aspects provides a finer control of train movement by giving train operators more information for controlling their trains over the next several blocks.¹⁶⁶

Adding aspects does not shorten the distance that trains require to stop but increases the precision with which the train ahead can be located, thereby reducing the excess train spacing. For example, when the lead train is occupying a block, the following train must be able to stop at the entrance to that block, but the lead train could be anywhere within the block, even at the end. Adding a fourth aspect to a three-aspect signal system cuts the block length in half, and the following train would receive a stop signal only if the lead train were within the 50 percent shorter block, meaning less space between the trains and greater capacity. This requires the following train to begin slowing down two blocks before the stop aspect; however, since the blocks are half the distance of a three-aspect system, this is the same distance.

For example, if the block length in a three-aspect signaling system is 7,000 feet, the following train would need to prepare to stop when the lead train was anywhere between 7,000 and 14,000 feet away; excess train spacing would be 7,000 feet and over. If a fourth aspect were added to this line, the following train would need to start slowing down only when the lead train was 7,000 to 10,500 feet ahead; excess train spacing is reduced to 3,500 feet. Thus, adding aspects enables following trains to control their speeds more precisely. (See Figure 10 on page 63.)

There is a limit to the efficiency of adding aspects, as each aspect added reduces the excess train spacing by 50 percent. Therefore, going from three to four aspects is twice as effective as going from four to five aspects.

Improve Communications—Automatic Cab Signaling

As train speed increases, so does the possibility that a train operator will not see a wayside signal, which creates a significant safety hazard. Missed signals are a leading cause of train accidents and have caused several serious passenger train accidents in recent years. Automatic cab signaling (ACS) provides train control information to train operators by displaying signal aspect information on the operator's control panel in the cab and sounding an audible alarm when the train passes into a block with a more restrictive signal aspect. U.S. government regulations require cab signaling or train control systems for operations above 79 mph.¹⁶⁷

The two types of ACS are intermittent and continuous. The intermittent type displays the last signal's aspect until the train passes the next signal, at which time the new signal's aspect is displayed. Continuous cab signaling displays the signal aspect in real time, providing more accurate and precise information to the operator. In a continuous system, if the signal aspect changes mid-block to more permissive, the operator can immediately increase the train speed, but with intermittent signaling, the operator would not receive that information (and, therefore, could not increase speed) until the start of the next block. Providing continuous information directly to the operator enables more precise train control, improving the railroad system's capacity and efficiency.

Train Control Systems—Automatic Train Stop and Automatic Train Control

Automatic cab signaling provides information to the train operator but does not require the operator to act upon the information. Train control systems take control of the train if the operator does not take appropriate actions after receiving signal information. Train control systems are referred to by different names (for example, positive train control) in different countries and even on different railroads operating within a single country.

The simplest type of train control is an automatic train stop (ATS) system. These operate with the same wayside-to-train signals (continuous or intermittent) as automatic cab signaling systems but also have an interface with the train braking system. An ATS system stops the train automatically if the operator does not take the appropriate actions when the train encounters a restrictive signal.¹⁶⁸

A higher level of control is provided by automatic train control (ATC), which not only stops a train but also controls its speed. An ATC system receives maximum speed information from beacons located at fixed locations along the tracks (for example, safe operating speed on a curve) and communicates that information to an on-board computer, which converts the information for display on the operator's panel. If the operator does not take appropriate action, the system automatically reduces train speed or stops the train. One especially good feature of ATC is that the beacons can be located independently of the signal system and the information supplied by the beacons can be combined with train characteristics (programmed in the train's on-board computer) to control train speed and operation precisely.

Another approach is the Incremental Train Control System, which overlays an alternative signal system over the basic system, enabling different types of trains to share tracks more efficiently.¹⁶⁹

In the United States, a significant effort is underway to develop an ATC system for the Northeast Corridor. This system, the Advanced Civil Speed Enforcement System (ACSES), is designed to migrate the NEC from the present four-aspect continuous cab signal system to a nine-aspect continuous cab signal/speed control system. The ACSES will provide for train operations up to 150 mph.¹⁷⁰ Other U.S. research efforts are underway in the Midwest with the North American Joint Positive Train Control Project and Incremental Train Control System in Michigan.¹⁷¹ Although these systems seem to work well for passenger trains, a key problem under study is their difficulty in modeling complicated freight train movements, such as switching.¹⁷²

European railways have joined together to develop the ERTMS Project. This system will consist of the European Train Control System (ETCS), a European Integrated Railway Radio Enhanced Network (EIRENE), and harmonized rules and regulations for the new ERTMS command and control system. The ETCS has the following three levels:¹⁷³

- ETCS Level 1—Standardized Automatic Train Protection overlaid on traditional systems. At this level, trains receive information from trackside beacons (balises) on speed and movement authorities. Safe speed control is ensured by the existing signaling infrastructure.
- ETCS Level 2—Radio-Based Signaling with Fixed Blocks introduces an on-board radio system and computer that communicates information about the train's position and performance to and from the control center directly from the train. The control center radios movement authority to the trains, and the train's on-board computer (preprogrammed with line information) calculates the speed profile for the segment.
- ETCS Level 3—Radio-Based Signaling with Moving Blocks uses the same control systems as Level 2, but adds moving block operations. As outlined above, in a moving block system, block lengths change depending on train characteristics and track conditions. Moving block operations is expected to add capacity to railroad operations by allowing trains to be run closer together; however, this system is probably needed only on the most congested lines.

The U.S. program is similar to ETCS Level 2. Switzerland is currently installing an ETCS Level 2 system on its route between Zurich and Bern, which is scheduled to begin operations at the end of 2004. This system was needed to achieve the SBB's goal of operating 27 trains per hour at speeds up to 200 km/h (125 mph).¹⁷⁴

Although automatic train control systems are currently used in railroads only to reduce speeds, similar systems in rapid transit systems control all train operations, including accelerating to safe operating speeds; the operator is only needed for special situations and emergencies. The SNCF considered implementing such automatic train control systems for the TGV system but decided that it was better for the operators to be responsible for train speed so that they remained attentive. They also have found that, in some cases, operators are more efficient than automated systems.

Train Control System Recommendations

All trains operated on a shared-use high-speed rail system should have automatic train control systems for safety, capacity, and speed reasons. For safety reasons alone, shared-use HSR systems should operate with as much train control as possible.^{175, 176}

A major problem is that, to achieve the real benefits of train control systems, all the trains operating on the route must have compatible equipment. For example, to take advantage of increased speed limits from cab signaling, all locomotives must be equipped with cab signals. In the United States, this could mean installing cab signaling in all locomotives because, theoretically, any locomotive can be used on any track. However, there should be operational strategies to limit the number of locomotives that need to be equipped with train control equipment. This again shows the need for a good working relationship between stakeholders,

since negotiating workable solutions between different shared-use system users will be critical to the system's overall success.

INTERLOCKING SYSTEMS

The second main type of railroad control system is an interlocking. An interlocking is a place where railroad tracks meet, which has a signal system and mechanical controls in place to prevent trains from colliding. Thus, an interlocking is a combination of track and signal system infrastructure; the track part is described in Chapter 5, and this section focuses on the interlocking signal system. The word “interlock” refers to the concept that enabling a train to take a certain path (by throwing a switch allowing the train to change tracks) causes a series of other connected actions (for example signal changes) that prevent other trains from conflicting with the train switching tracks.

An interlocking is used in routing a train through the railroad track network. Normally, a controller sets up a route for a train through a switch or series of switches, and the interlocking ensures that this route is reserved for that train and prohibits conflicting train movements. The signal system then displays aspects that the train operator uses to determine train speed. (The speed a train can go straight through a switch is higher than if the train is changing tracks.) Interlocking signals also function as block signals to prevent rear-end collisions.¹⁷⁷

A simple example of an interlocking is a switch and signals that enable trains to change from one track to the other on a two-track line. The interlocking system prevents one train from switching to another track if there is danger of colliding with another train. In this case, the interlocking equipment would prevent the switch from being thrown to allow the train to switch tracks. As this simple example indicates, interlockings are a complex subject.

For shared-use high-speed rail systems, all interlockings should be designed to ensure that they do not delay trains or cause capacity problems. This could mean building additional tracks through complicated interlockings to provide a fast path for high-speed trains. Complex terminal areas usually need detailed human analysis to ensure that interlocking configurations provide not only for routine revenue moves, but also for the various switching and yard moves.¹⁷⁸

Because interlockings are critical to train operations, they must be extremely reliable; with high levels of train service and the importance of schedule reliability in shared-use high-speed rail systems, no downtime for interlockings is acceptable. This means developing reliable designs and purchasing highly reliable equipment.¹⁷⁹

TRAFFIC CONTROL SYSTEMS

The third type of railroad control system is traffic control. Railroad lines that are signaled so that trains can run on tracks in both directions operate under traffic control system rules rather than ABS and interlocking rules. In a centralized traffic control (CTC) system, all the interlockings and manually controlled points are controlled remotely from a central location.¹⁸⁰ CTC is not a separate control system—it uses the block signal system and interlockings to control train movements (although radio communications between the dispatcher and train crews are available).

CTC is commonly used on busy railroad lines. It allows trains to be routed through complex track networks (a series of interlockings) to optimize performance of the overall railroad system. Train movements on CTC segments of track are controlled by dispatchers who have information on the position of all the trains in their segments and infrastructure information such as the position of switches. Dispatchers give train operators instructions and control train routing in real time by remotely controlling signal systems and track infrastructure and by talking directly with train operators by radio.

Introduction of a CTC system increases railroad capacity by increasing the degree of system control; for example, a single-track railroad with sidings and CTC has up to 70 percent of the capacity of a double-track ABS railroad.¹⁸¹ A CTC system allows the dispatcher to safely direct overtakes of trains traveling in the same direction and meets of trains traveling in opposite directions on one-track railroads by enabling the dispatcher to place a train in a siding or on an additional mainline track.

Given the complexity of operating a shared-use high-speed rail system, in terms of the number and types of trains as well as the infrastructure constraints inherent in a shared-use system, it is strongly recommended that any shared-use high-speed rail system use central traffic control. Chapter 7 presents some recommended operating strategies for shared-use high-speed rail systems that can be implemented with a CTC system.

CHAPTER 7. OPERATING STRATEGIES

This chapter describes operating strategies for improving shared-use high-speed rail systems. Operating strategies can be defined as plans for providing transportation services on the shared-use segments of track. Two types of operating strategies will be described: operations planning, which consists of preparing schedules and plans in advance, and dispatching, which consists of techniques for managing day-to-day railroad operations.

OPERATIONS PLANNING

Operations planning consists of developing a schedule for all the trains that will be run on the shared-use segment. Except for relatively simple systems, this requires the use of train simulation software to develop an optimized schedule for a particular mixture of train operations. Simulation programs enable schedulers to evaluate various schedules to identify the one that is most efficient and reliable. Several strategies can be used to improve the mixture of trains that can be scheduled and to set basic ground rules for scheduling based on the needs of the shared-use high-speed rail system. These strategies are outlined below.

- **Limit Train Variation Through Scheduling**—One of the most important strategies for improving shared-use high-speed rail systems is to reduce the variation of train types operating at any given time. An example of this is requiring that all freight trains travel at night when there is only limited passenger service (a common practice on European railroads). Most of the trains operating during the day could operate at higher speeds and with shorter headways. This would increase daytime capacity and speeds.
- **Make Freight Trains Similar to Passenger Trains**—Another option is to change the characteristics of freight trains so that they operate more like passenger trains by providing for more power and improve braking ability. This might mean short, fast freight trains during the day—perhaps a new market for freight operators.¹⁸² Many European railroads now operate limited amounts of this type of freight service, and U.S. railroads are experimenting with fast cross-country container trains.
- **Rerouting Trains**—Specific trains might be routed over other vaguely parallel railroad lines. Although the infrastructure on these lines might need improvements for them to be used, that might be more cost effective than improving the high-speed route to serve all trains. A good example would be rerouting freight trains from the high-speed route to another route.¹⁸³ This strategy could be used throughout the day or for trains during a particular time when there was high passenger train demand for the shared-use route.
- **Revised Service Plan**—A significant problem on shared-use segments with different types of passenger service are conflicts between local passenger trains that stop frequently, such as commuter trains, and higher-speed trains that stop less frequently. Revising the service plan

means developing new schedules that minimize the conflicts between trains. Rail system planning in Switzerland uses this concept extensively.¹⁸⁴ Among the many strategies used to achieve this objective are the following:

- **Skip Stop Service**—Stopping local trains only at selected stations can speed up service on a segment.
- **Break Up Local Service**—This means separating routes into segments, providing local service on the segments with connecting service at the main stations. This may make it possible to schedule local trains to operate on a schedule that does not interfere with the higher-speed services on that segment. High-speed trains would pass local trains at multiple track stations.
- **Speed Scheduling**—This sets the fastest trains to start first, followed by slower trains. In a version of this called “zone scheduling,” the first train goes a long distance then stops at all the stops, the second train goes a shorter distance then stops at all the stops, the third train goes a shorter distance then stops at all the stops, and so on. This type of schedule works best for a commuter system where most of the ridership originates at one station and no special provisions are made for intermediate riders.¹⁸⁵
- **Eliminate Local Station Stops/Trains**—Eliminating local stops speeds up local trains, reducing conflicts; eliminating trains provides more capacity for high-speed trains. In both cases, alternative service should be provided, for example, by bus.
- **Bundling Trains**—This consists of creating a train schedule with a repeating pattern. For example, a fast train leaves every half hour and a regional train leaves five minutes afterward, throughout the day.¹⁸⁶ Using bundling, the infrastructure required to allow trains to overtake or pass will be located in the same places for each bundle of trains, minimizing the amount of infrastructure required. It also provides more convenient service for customers, since they can more easily remember a repeating schedule. Switzerland, The Netherlands, and Germany all use this type of clockface scheduling to improve customer service and reduce infrastructure costs.¹⁸⁷
- **Maintenance Windows**—These are times when segments of the track network are set aside for maintenance and repairs. Including regular maintenance windows in the operating plan for the shared-use sections of track improves the system’s reliability and efficiency. One reason for the high efficiency of dedicated high-speed rail systems (and shared-use systems with significant shares of dedicated line) is that they have long track-availability windows during the night when high-speed trains are not operating, during which infrastructure can be maintained and improved.

DAY-TO-DAY OPERATIONS

Operations planning consists of developing an optimized schedule in advance, but day-to-day operations focuses on what happens when things do not work as planned. Train delays or

infrastructure failures are typical examples of things going wrong. Shared-use high-speed rail systems include different train types and generally high train volumes, creating many opportunities for problems to occur; furthermore, problems that do occur usually impact many trains.

Given the volume of traffic and need for control that is inherent in a shared-use high-speed rail system, Chapter 6 recommended that all such systems operate with centralized traffic control (CTC). Although a CTC system enables dispatchers to route trains through the network and provide instructions to train operators, people must set priorities and make good decisions. Among the recommendations that can help improve day-to-day operations on a shared-use high-speed rail system are the following:

- **Single Dispatching System**—The best situation for the high-speed rail operator would be to control the dispatching on the entire shared-use system (both dedicated track and shared-use track). The high-speed service could operate in the best possible manner because high-speed trains would have priority in all cases. It is unlikely that this would be possible in most shared-use systems because shared-use segments generally are owned by another railroad. In some cases, the shared-use segments could be purchased to gain control over dispatching, but this could be expensive and time consuming. However, purchasing segments would be unnecessary if all the rail service operators could agree on a common dispatching strategy that minimizes the impacts of problems on all users (see below). Another strategy that can be used, if it is impossible to adopt a single dispatching system, is to colocate dispatching centers from different operators. Amtrak and New Jersey Transit improved operations on their shared-use line by building a joint dispatching center.¹⁸⁸
- **Priority System**—The most important tool for a dispatcher is a clear priority system, identifying which train has priority in any given situation. If all trains have equal priority, a delayed high-speed train might miss its slot in the schedule and be significantly delayed by an on-time commuter train running just ahead of it; alternatively, if high-speed trains always have first priority, the dispatcher could instruct the commuter train to wait until the high-speed train passed it before proceeding, reducing delay to the high-speed train but increasing delay for the commuter train. There are many ways to set priorities. In The Netherlands, the Minister of Transportation sets priorities.¹⁸⁹ Different train operators on the shared-use segment need to negotiate an approach to addressing delays and problems that minimizes the impacts to all users. Such an approach will likely consist of setting priorities for various types of trains in different situations.¹⁹⁰
- **Computerized Dispatching Assistance**—Not even the best dispatcher can fully optimize the operations of a complicated segment of shared-use high-speed rail system. Computerized decision support systems should be developed to help dispatchers route trains optimally through the system in different situations.¹⁹¹ For example, the system

could estimate delays for different trains under different alternatives and provide this information to assist the dispatcher in making the best choice. One type of information that would help dispatchers in shared-use systems would be knowing in real time when high-speed trains will arrive at the shared-use segment. This is a similar situation to through-trains traveling throughout different European countries, and a software system is being developed to provide information to train controllers in different countries to minimize the impacts of delayed trains on the system and on the delayed train itself.¹⁹²

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ABBREVIATIONS AND ACRONYMS

ABS	Automatic Block Signaling
ACS	Automatic Cab Signaling
ACSES	Advanced Civil Speed Enforcement System
AREMA	American Railway Engineering and Maintenance-of-Way Association
ATC	Automatic Train Control
ATS	Automatic Train Stop
CTC	Centralized Traffic Control
CWR	Continuously Welded Rail
EIRENE	European Integrated Railway Radio Enhanced Network
EPFL	Ecole Polytechnic Federal Lausanne
ETCS	European Train Control System
FRA	Federal Railroad Administration
HSR	High-Speed Rail
ICE	InterCity Express (German high-speed train)
ICE-T	InterCity Express, tilting version
ISTEA	Intermodal Surface Transportation Efficiency Act
NEC	Northeast Corridor (Boston to Washington, D.C., United States)
PBQD	Parsons Brinkerhoff Quade & Douglas
SBB	Swiss National Railroad
TEA-21	Transportation Equity Act for the 21 st Century
TGV	Train à Grande Vitesse (French high-speed rail system)
TRB	Transportation Research Board

APPENDIX A. INTERVIEW LIST

Best Practices Shared-Use High-Speed Rail Systems

- Braendli, Heinrich; Professor, Transportation Planning and Railroad Engineering, ETH Zurich; Interview, January 2002.
- Cunningham, J.J.; Chief Engineer–Planning, Policy, Standards, Amtrak; Interview, January 2002.
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APPENDIX B. INITIAL QUESTIONNAIRE

Best Practices Shared-Use High-Speed Rail Systems

Shared-Use of Rail Infrastructure by High-Speed Rail: Best Practices

Questionnaire

The questions below have been designed to solicit information from railroad professionals on shared-use of rail infrastructure between high-speed rail and other rail traffic. The goal is to identify a series of best practices for infrastructure and operations for shared-use of rail facilities.

Thank you for your assistance.

Andrew Nash – nashtimm@freesurf.ch

1. Where does your railroad use shared-use operations?
2. Why does it use shared-use in these areas?
3. How does shared-use of rail infrastructure on your railroad work? For example, is there a priority system? Is there a basic philosophy behind shared-use?
4. Who controls the track dispatching on your railroad? What impact does this have on your operations and infrastructure planning?
5. Does your railroad use any particular *operating techniques* to minimize the impacts of shared-use?
6. How was the question of shared-use versus new infrastructure evaluated in planning your railroad? Would you make any changes to the evaluation process based on operating experience?
7. How did the facility design and operating philosophy work together?

8. Can you describe some examples of infrastructure (for example, stations, signaling, track, and structures) designed with shared-use in mind that work particularly well?
9. Can you describe some examples of infrastructure that you would like to improve?
10. In general, how well would you say the shared-use system is working on your railroad?
11. What would you do to improve the shared-use operation? (Infrastructure, operations?)
12. Do you know of any other people in the USA or Europe who should be contacted in this study? Particularly people at railroads doing something unique that you would like to learn more about?

ABOUT THE AUTHOR

The report's principal author was Andrew Nash, an independent transportation planning consultant living in Zurich, Switzerland. Nash was Executive Director of the San Francisco County Transportation Authority before moving to Europe. As Executive Director of the Transportation Authority, he was responsible for managing a government agency with an annual budget of more than \$100 million. The Authority allocated funds for capital projects to the city's transportation agencies and completed long-range transportation planning for San Francisco.

Before coming to the SFCTA, Nash was Project Manager for the Caltrain commuter railroad. There he directed several large and controversial transportation engineering studies, including extending the railroad to a new multimodal transportation terminal in downtown San Francisco and an airport-rail-Caltrain connection project. Nash came to Caltrain from Santa Clara County, where he was Director of Congestion Management.

Nash earned a Master of Civil Engineering and a Master of City Planning from the University of California, Berkeley in 1987. He earned a Master of Science in Transportation from Northeastern University in 1983 and a Bachelor of Science in Civil Engineering from Rensselaer Polytechnic Institute. He is a registered Professional Civil Engineer in California.

Nash has authored several publications, most recently *Implementation of Zurich's Transit Priority Program* (available at www.transweb.sjsu.edu). Other publications include "Caltrain Rapid Rail Program," TRB Annual Meeting 1999; "Public Decision Making for the Caltrain Downtown San Francisco Extension Project," Transportation Research Record 1571, March 1997; "California's Congestion Management Program," ITE Journal, February 1992; "Effective Citizen Involvement in the Transportation Planning Process," TRB Annual Meeting, 1990; and "Vehicle Pooling in Transit Operations" (with Peter Furth), American Society of Civil Engineers, *Journal of Transportation Engineering*, May 1985.

Nash has also served as an officer for several nonprofit organizations in the San Francisco Bay Area, including President of Greenbelt Alliance and Board Member of the San Francisco Urban Planning and Research Association. Nash also ran unsuccessfully for election to the Bay Area Rapid Transit District Board of Directors in 1992.

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131. The Japanese and German ICE systems use slab track on dedicated lines.

132. John B. Hopkins, op. cit., 7.

133. See www.trainweb.org/tgvpages/track for more information on the TGV track construction.

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158. John H. Armstrong, op. cit. Page 128 presents the idea of thinking of discussing signaling system operations in terms of preventing rear-end, side-on and head-on collisions.

159. K.B. Ullman and A.J. Bing, (1) op. cit. See Figure 1, "Safe Braking Distance," on p. 39. This article is a summary of Report DOT-VNTSC-FRA-94-11, cited above.

160. *Ibid.*, 49.

161. It can be argued that moving block technology does not provide significant advantages over continuous automatic train control systems which provide speed data to trains at all times. The added expense and complication of moving block systems calls into question their effectiveness. SBB XP Group Bern, Felix Laube, interview by author, March, 2002.

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162. K.B. Ullman and A.J. Bing, (1) op. cit., p 42. This reference also provides a good example of the magnitude of capacity reduction with operation of different types of trains under different circumstances.
163. SBB Bern XP Group, interview by author, March 2002. For example much of the Swiss railway network was built as single track with passing sidings. The network has been double-tracked by extending the sidings, but in many places the signals are still located where the sidings were.
164. Steve McAvoy, interview by author, February 2002. A good example of rebuilding a signal system is on the Caltrain commuter railroad in the San Francisco Bay Area; this project will be completed with the idea of operating shared use high-speed rail in the future.
165. Federal Railroad Administration, *Railroad Corridor Transportation Plans*, 4.
166. Adding aspects is described in almost all signal system references. A good description is presented in John H. Armstrong, *The Railroad—What It Is, What It Does*, 131, with a good diagram on page 132.
167. John H. Armstrong, op. cit., 136.
168. K.B. Ullman and A.J. Bing, (1) op. cit., 41.
169. Dick Cogswell and Steve Ditmeyer, “Session 2—Signals and Train Control,” TRB Workshop on Railroad Capacity and Corridor Planning, 13 January 2002, handout, 22.
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177. This describes speed signaling. In route signaling the signal system indicates tells the operator that the train will be going straight or switch to another track, the operator must know what speed is appropriate for that situation. See Armstrong, op. cit., 137.

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180. K.B. Ullman and A.J. Bing, (1) op. cit., 39.

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182. Paul Richardson.

183. Rick Wilson, "Session 6–Single Track Capacity Issues, Part 1," TRB Workshop on Railroad Capacity and Corridor Planning, Washington, D.C., January 2002, handout. Also Alex Lu.

184. Peter Grossenbacher, op. cit, 118. Also, SSB XP Group Bern.

185. Stephen McEvoy, *Caltrain Capital Project*.

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192. Anne Curchod and Maurice Genête, "OPTIRAILS: Optimization of traffic through the European rail traffic management systems," paper presented at Swiss Transportation Research Conference 2002.

PREPUBLICATION PEER REVIEW

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