

Estimating Workforce Development Needs for High-Speed Rail in California



MTI Report 11-16



MINETA TRANSPORTATION INSTITUTE

The Norman Y. Mineta International Institute for Surface Transportation Policy Studies was established by Congress in the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). The Institute's Board of Trustees revised the name to Mineta Transportation Institute (MTI) in 1996. Reauthorized in 1998, MTI was selected by the U.S. Department of Transportation through a competitive process in 2002 as a national "Center of Excellence." The Institute is funded by Congress through the United States Department of Transportation's Research and Innovative Technology Administration, the California Legislature through the Department of Transportation (Caltrans), and by private grants and donations.

The Institute receives oversight from an internationally respected Board of Trustees whose members represent all major surface transportation modes. MTI's focus on policy and management resulted from a Board assessment of the industry's unmet needs and led directly to the choice of the San José State University College of Business as the Institute's home. The Board provides policy direction, assists with needs assessment, and connects the Institute and its programs with the international transportation community.

MTI's transportation policy work is centered on three primary responsibilities:

Research

MTI works to provide policy-oriented research for all levels of government and the private sector to foster the development of optimum surface transportation systems. Research areas include: transportation security; planning and policy development; interrelationships among transportation, land use, and the environment; transportation finance; and collaborative labor-management relations. Certified Research Associates conduct the research. Certification requires an advanced degree, generally a PhD, a record of academic publications, and professional references. Research projects culminate in a peer-reviewed publication, available both in hardcopy and on TransWeb, the MTI website (<http://transweb.sjsu.edu>).

Education

The educational goal of the Institute is to provide graduate-level education to students seeking a career in the development and operation of surface transportation programs. MTI, through San José State University, offers an AACSB-accredited Master of Science in Transportation Management and a graduate Certificate in Transportation Management that serve to prepare the nation's transportation managers for the 21st century. The master's degree is the highest conferred by the California State University system. With the active assistance of the California

Department of Transportation, MTI delivers its classes over a state-of-the-art videoconference network throughout the state of California and via webcasting beyond, allowing working transportation professionals to pursue an advanced degree regardless of their location. To meet the needs of employers seeking a diverse workforce, MTI's education program promotes enrollment to under-represented groups.

Information and Technology Transfer

MTI promotes the availability of completed research to professional organizations and journals and works to integrate the research findings into the graduate education program. In addition to publishing the studies, the Institute also sponsors symposia to disseminate research results to transportation professionals and encourages Research Associates to present their findings at conferences. The World in Motion, MTI's quarterly newsletter, covers innovation in the Institute's research and education programs. MTI's extensive collection of transportation-related publications is integrated into San José State University's world-class Martin Luther King, Jr. Library.

DISCLAIMER

The contents of this report reflect the views of the authors, who are responsible for the facts and accuracy of the information presented herein. This document is disseminated under the sponsorship of the U.S. Department of Transportation, University Transportation Centers Program and the California Department of Transportation, in the interest of information exchange. This report does not necessarily reflect the official views or policies of the U.S. government, State of California, or the Mineta Transportation Institute, who assume no liability for the contents or use thereof. This report does not constitute a standard specification, design standard, or regulation.

REPORT 11-16

ESTIMATING WORKFORCE DEVELOPMENT NEEDS FOR HIGH-SPEED RAIL IN CALIFORNIA

Peter J. Haas, PhD
Paul D. Hernandez, MPIA
Katherine Estrada, MPA

March 2012

A publication of

Mineta Transportation Institute

Created by Congress in 1991

College of Business
San José State University
San José, CA 95192-0219

TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No. CA-MTI-12-1027	2. Government Acession No.	3. Recipient's Catalog No.	
4. Title and Subtitle Estimating Workforce Development Needs For High-Speed Rail In California		5. Report Date March 2012	
		6. Performing Organization Code	
7. Authors Peter J. Haas, PhD, Paul D. Hernandez, MP IA, Katherine Estrada, MPA		8. Performing Organization Report MTI Report 11-16	
9. Performing Organization Name and Address Mineta Transportation Institute College of Business San José State University San José, CA 95192-0219		10. Work Unit No.	
		11. Contract or Grant No. DTRT07-G-0054	
12. Sponsoring Agency Name and Address California Department of Transportation U.S. Department of Transportation Office of Research—MS42 Research & Innovative Technology Admin. P.O. Box 942873 1200 New Jersey Avenue, SE Sacramento, CA 94273-0001 Washington, DC 20590		13. Type of Report and Period Covered Final Report	
		14. Sponsoring Agency Code	
15. Supplemental Notes			
16. Abstract <p>This study provides an assessment of the job creation and attendant education and training needs associated with the creation of the California High-Speed Rail (CHSR) network, scheduled to begin construction in September 2012. Given the high profile of national and state commitment to the project, a comprehensive analysis that discusses the education, training, and related needs created during the build out of the CHSR network is necessary. This needs assessment is achieved by means of: 1) analyzing current high-speed rail specific challenges pertaining to 220mph trains; 2) using a more accurate and robust "bottom-up" approach to estimate the labor, education, skills, and knowledge needed to complete the CHSR network; and 3) assessing the current capacity of railroad-specific training and education in the state of California and the nation. Through these analyses, the study identifies the magnitude and attributes of the workforce development needs and challenges that lie ahead for California.</p> <p>The results of this research offer new insight into the training and education levels likely to be needed for the emergent high-speed rail workforce, including which types of workers and professionals are needed over the life of the project (by project phase), and their anticipated educational level. Results indicates that although the education attained by the design engineers of the system signifies the most advanced levels of education in the workforce, this group is comparatively small over the life of the project. Secondly, this report identifies vast training needs for the construction workforce and higher education needs for a managerial construction workforce. Finally, the report identifies an extremely limited existing capacity for training and educating the high-speed rail workforce in both California and in the U.S. generally.</p>			
17. Key Words Persons by educational level; Education and training; Employment; Regional railroads; Research and educational facilities	18. Distribution Statement No restrictions. This document is available to the public through The National Technical Information Service, Springfield, VA 22161		
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 160	22. Price \$15.00

Copyright © 2012
by **Mineta Transportation Institute**
All rights reserved

Library of Congress Catalog Card Number:
2011941827

To order this publication, please contact:

Mineta Transportation Institute
College of Business
San José State University
San José, CA 95192-0219

Tel: (408) 924-7560
Fax: (408) 924-7565
Email: mineta-institute@sjsu.edu
transweb.sjsu.edu

ACKNOWLEDGMENTS

The authors thank MTI staff, including Research Director Karen Philbrick, PhD; Director of Communications and Technology Transfer Donna Maurillo; Student Publications Assistant Sahil Rahimi; Student Research Support Assistant Joey Mercado; and Webmaster Frances Cherman. Additional editorial support was provided by Editorial Associate Mary Buuck. The authors also thank the anonymous peer reviewers and consultants Stan Feinsod and Dr. T.C. Kao.

TABLE OF CONTENTS

Executive Summary	1
I. Introduction	9
CHSR and Labor Impact/Linkages	9
Workforce Development as a Critical System Component	10
Critical Areas of HSR Technology	15
Data and Methods used in this Study	25
II. Estimates of Employment and Workforce Development	29
Introduction	29
Employment Estimates Summary	29
Total Employment Demand by Type of Position	30
Education Outcomes Summary	36
Education Impacts by Phase	40
Summary: Education Needs by Project Phases, 2009–2025	56
Workforce Development Needs during Peak Period	56
Preliminary Estimates According to the CHSRA 2012 BP	58
Conclusions	61
III. Existing Capacity for Preparing the HSR Workforce	67
Community College Capacity	67
Trades Training Capacity	68
Higher Education Capacity	68
The Role of Universities	70
U.S. University Programs Leading in Railway Engineering Training and Research	72
Other Approaches from U.S. Universities	73
Summary of Existing Railroad Higher Education in the United States	75
Industry Internships and On-the-Job Training	75
Interplay of University and Industry	76
Other Countries' Responses	76
Current State of Education and Training in California	83
Possible Means of Achieving Workforce Goals	88
The Future of HSR Education and Training in California	88

Appendix A: Data and Methods	91
Overview of the CHSR Project Delivery Method	91
DBOM	91
Existing Personnel Measurements of Infrastructure Projects	94
Measuring the CHSR Workforce	100
Design Phase Methods and Estimates	102
Construction Management Phase Methods and Estimates	105
Operations and Maintenance Methods and Estimates	116
Appendix B: Assumptions and Limitations Built into Labor Estimates	127
Endnotes	133
Bibliography	145
Abbreviations and Acronyms	155
About the Authors	157
Peer Review	159

LIST OF FIGURES

1. Total Personnel by Project Phase	4
2. Total Personnel by Estimated Level of Education	5
3. Bottom-up Estimation as a Process Flow	28
4. Mathematical Benchmark and Bottom-up Estimation, Personnel Wave 2009–2020	30
5. CHSR Personnel Wave, 2009–2025, Phase 1 of Project	31
6. PY by Phase	32
7. Education Needs, CHSR Network Build-Out	38
8. Education Needs by Degree, During Design Phase	42
9. Construction Management During Build Phase, Degree Demand, 2012–2019, Expressed in Personnel-Years	46
10. Construction Build Phase Degree Demand, PY, 2012–2019	51
11. Operations and Maintenance Phase Degree Demand, 2020–2025 Observed	55
12. Peak Demand for Phase 1, 2013–2016, CHSR Project	57
13. Peak Year(s), 2013–2016, CHSR Network Build-Out Education Demographic	58
14. 2012 BP CHSR Workforce Demand, Direct Personnel in PY, 2012–2034	59
15. Education and Training Levels, CHSR Project, 2012–2033	60
16. Education and Training Needs, CHSR Network Build-Out	62
17. Training, Community College, and Higher Education Need, During Peak Period, 2013–2016	64
18. National Key Discipline, School Specialization, and Department Specialization in Chinese Transportation Education Structure	77
19. Organizational Chart of Taiwan’s Railway Technology Research Center	81
20. Organizational Chart of KRII	82
21. Comparing Appropriations for Northeast Corridor Fiscal Years 1976–1995, in Real 1995 Dollars, and CHSRA 2008–2029, from CHSRA Report to Legislature	94

22. CHSR Network Program Management Cost, 2009–2020	103
23. Design: Estimated Personnel Purchasing Capability of Program Management Team Fixed-Cost Design Phase Professionals and Variable Program Management Personnel	105
24. Construction Management Personnel Estimation Direct-Cost Staff and Indirect-Cost Staff	107
25. Total Program Management and Construction Management Personnel Demand: Estimates of Personnel Through Fixed Cost and Indirect Costs	108
26. General Equation for Total Cost	110
27. Takeoff Factor, Generic Equation	111
28. Bottom-up Labor Estimation Steps	112
29. Bottom-up Measurement Sequence, Graphical Representation	113
30. CHSR Labor Quantity in PY	115
31. CHSRA Release, International Counterparts the Authority Consulted to Improve Operations and Maintenance Costs	118
32. Design and Build to Beginning of Operations, 2009–2020, Employment Estimations	119
33. Direct Personnel, 2009–2025, CHSR Network, Direct Personnel	122
34. Mathematical Benchmark and Bottom-up Estimation, Personnel Wave, 2009–2020	123

LIST OF TABLES

1. Peak Year(s), 2013-2016, CHSR Project	5
2. Summary of Data Used to Measure the CHSR Workforce, by Phase	26
3. Top-25 Professionals/Personnel Positions, Sequence of Demanded, and PY	33
4. Top-25 Professionals/Personnel Positions, Sequence of Demanded, and PY, Adjusted	35
5. Level of Education Expected to be Attained by the CHSR Workforce, by Year, 2009–2025	37
6. Total Direct Job Education Need Demographic By Phase, CHSR Network, 2009–2025	40
7. Top-Ten Types of Positions During Design Phase	41
8. Build Management Phase Education Needs	44
9. Build Construction Phase Education Needs, by Job Type, Top-Ten	48
10. Trades/Apprenticeships Build Construction Phase Labor and Worker Education Needs, Top-Ten	49
11. Build Construction Phase: Community College Education Needs, Top-Ten	50
12. Operation and Maintenance Phase, by Division	52
13. Operations and Maintenance Education Demographic, 1 Year Observed	53
14. Education Demographic by Phase, Recap	56
15. Peak Year(s), 2013–2016, CHSR Network Build-Out	57
16. Total Personnel, by Phase	61
17. Education Need, by Project Phase, 2009–2025	63
18. Existing Advanced Degree Training in Transportation Fields	84
19. California’s University Offerings in Transportation	86
20. Engineering Degrees from the UC and CSU Systems, Annually (2007–2009)	87
21. Segment and Personnel Employed, CHSRA	97
22. APTA Jobs per \$1 billion, Economic Development Research Group Modeling	98
23. APTA Jobs Per \$1 billion, Economic Development Research Group Modeling, as a Percentage, Showing Differences in Capital, Operations, and Blended Average Ratios	98
24. Summary of Data Used to Measure the CHSR Workforce	101

25. Program Management Project Implementation Costs: San Francisco to Anaheim	103
26. Variations of Operational and Maintenance Estimates, CHSR Network (2020 onward)	117
27. Measurement Methodology Used to Measure Personnel, by Phase	120
28. Example of Labor Education Needs for Construction Workers	124

EXECUTIVE SUMMARY

WORKFORCE AND EDUCATION IMPLICATIONS FOR CONSTRUCTING CALIFORNIA'S HIGH-SPEED RAIL SYSTEMS

Given the high profile of national and state commitments to the construction of high-speed rail (HSR) corridors, a comprehensive analysis that discusses the education, training, and related needs that will be created during the build out of the national HSR network is required. At present, relatively little research has explored the linkage between creating HSR systems and identifying the details of the workforce that will create it. Given the advent of national HSR systems and the accompanying lack of research that identifies workforce needs, we provide rich detail concerning the size as well as education and training backgrounds necessary for the HSR workforce in California.

This project examines in depth the workforce demands that will be created during the construction of an HSR network in California. Specifically, this research investigates various types of gaps in technology, information, and knowledge needs, with a focus on the training/education needs that will exist during the project's design, construction, and operation. These various levels of need are explored both qualitatively ("What kinds of jobs and training?") and quantitatively ("How many jobs and training slots?") to help identify proper levels of education system response. We also examine the existing capacity of the state's education and training facilitates to address such needs.

GOALS OF THE PROJECT

This project seeks to identify the workforce development of an HSR system in California. Generally, the project addresses the need for qualified individuals in three ways: (a) qualitatively, with the goal of specifying as finely as possible the individual positions and associated skill and knowledge sets; (b) quantitatively, with the goal of estimating the number of each type of position that will be associated with various phases of the project throughout its initial lifetime; and (c) by identifying as specifically as possible the training and education needed by these individuals. Finally, the project examines existing capacities for supplying the kinds of qualified workers identified in the context of the California system of education. To achieve these goals, the project will entail the following tasks:

- Identify and describe the sequence of the CHSR network build, using the design, build, operations, and maintenance (DBOM) process as a template. In so doing, we will recognize the similarities and differences characterized by each phase of the sequence as well as the possibilities for positions that may cross-cut or evolve over it.
- Identify the types of professionals and other workers associated with each sequence, establish their roles and responsibilities, and assess their skills, traits, and education.
- Identify specific types of technology that help frame activities for each position type during each sequence, identifying areas of overlapping skills and unique skills.
- Estimate approximate numbers of each type of position required during each phase (and year) of the project, also per the DBOM process, adding accuracy and specificity to existing estimates.

- Identify how other countries are addressing workforce and associated technological challenges of HSR, with an eye toward developing recommendations for California and the United States.
- Identify the capacity of the California education system and other institutions to deliver HSR-related training and education.

METHODS

We utilize three main methods and sources of data to analyze the needs that are created by the construction of the HSR network: (a) We draw from past, similar efforts of technologically demanding infrastructure projects to establish some qualitative, overarching areas of need; (b) we use a largely unprecedented quantitative model to establish hard data that show personnel/professional need over the life of the CHSR project; and (c) we assess the existing national and California-focused transportation infrastructure. In completing these analyses, we provide insight into the supply and demand of workforce needs associated with the construction of the CHSR network.

Method One: Qualitative, Through Identifying Areas of HSR Technological Demand

The first approach is a broad consideration of largely qualitative factors that likely will emerge as the result of building an advanced HSR infrastructure, focusing on specific aspects of knowledge, information, and technological need—each connected to the creation and operation of 220-mph HSR trains. We draw parallels from challenges faced by nations in the construction of their HSR networks. We further assess the current national state of HSR-specific technological capability by comparing the United States to some foreign systems, assess national HSR knowledge through discussing current research and development capabilities in the United States, and suggest opportunities to facilitate information capture and spin-off opportunities for HSR technologies.

Method Two: Quantitative “Bottom-up” Estimation

To identify the education and training impacts of building the CHSR system, a quantitative inventory of workforce needs is constructed. This second approach focuses on measuring the quantity of personnel/professionals needed over the life of the project. This is done through the creation of robust statistical measurement of the types, skills, and level of education of the personnel/professionals needed to complete the DBOM of the CHSR, focusing on the publically announced 2009–2025 period. We improve upon the widely used method of the prevailing “top-down” estimating methodology to establish detailed measurements of the direct personnel/professionals workforce. Our “bottom-up” method identifies estimates of the professionals/personnel needed in the design, construction management, construction build, and operations and maintenance phases, according to task and activity. This method creates extremely detailed personnel estimates needed to create the CHSR infrastructure. We create a visualization of the direct personnel needs by phase, sector, and job type, over the life of the project, and identify peak periods of demand.

Further, we link the personnel estimates to the education and training needs of the new HSR workforce. We create the **CHSR Workforce Impact Index**, which details the

estimated education needs created by the needs for personnel/professionals over the life of the project.

Method Three: Identifying Current Rail Education Capabilities

Accepting the established needs identified both quantitatively and qualitatively by the first two approaches, the third methodology identifies current education infrastructure surrounding HSR-related disciplines in the United States, and more broadly identifies the transportation-focused aptitude of the California education infrastructure. We identify possible areas of concern related to current levels and loci of capability. Further, we draw out broad comparisons with rail education in foreign nations, including European, Japanese, Taiwanese, and Korean structures through which research and development, collaboration, and education are facilitated, and identify the lack of similar education capability in the United States.

FINDINGS

In the first section of this report, we explain how HSR and conventional rail are fundamentally different systems, thus creating need for information, knowledge, and technology in at least six key areas which translate to potential demands for education and training in these areas. Preliminary findings suggest that factors related to these areas that may challenge the university systems and training networks in the design of the technologies in each of the areas:

- Increases in the need to understand noise and vibration, and increases in the capability and capacity to design technologies to mitigate such emissions.
- Demand for advanced train control/signaling/collision prevention, and Positive Train Control systems that—although present in foreign systems—have not been previously deployed in the United States.
- Need for technology and understanding of acceleration and deceleration characteristics of HSR trains, especially in the efficient management of energy throughout the system.
- Increased need for the design of a comprehensive communications network/monitoring system, which has not yet been deployed with 220-mph capability in the United States, although foreign models have deployed such systems.
- Expanded need for the design and implementation of sensory-based intrusion prevention and detection and natural disaster detection technologies (especially earthquake).
- Increased knowledge and technology needed for the maintenance of systems and rolling stock for new and sophisticated HSR systems.

In the second section of this report, we detail the needs for a massive workforce, along with implications for their training and education needs. We also detail the education and training needs associated with the peak periods of demand for these personnel/professionals.

Total Direct Personnel Workforce (in Personnel-Years; PY)

Focusing only on direct demand created by the HSR project, we estimate total workforce demand at 256,092 direct jobs (in PY) over the life of the project, from the 2009-2025, according to the projections of the 2009 Business Plan (BP) (see figure 5). We use PY as the unit of measure to uniformly estimate personnel across years of the project.

PY by Project Phase, as a Percentage, and Total Personnel by Level of Education

We disaggregate our total estimate of 256,092 direct jobs (PY) into project phases to identify the personnel/professionals demanded during that time (design: 1 percent, build management: 7 percent, build construction: 79 percent, and operations and maintenance: 13 percent) to examine sector impacts (see figure 1).

We then connect the projected HSR workforce to its likely education (see figure 2). What emerges are rich projections of the total education need of the directly employed workforce, over the 2009–2025 period. The training need for trades/construction at the high-school and below level constitutes 67.4 percent of the total workforce. Some college training or education (no degree), including A.A./A.S. certification, constitutes 18.73 percent of the total workforce training needs. The higher education needs constitute 12.88 percent of the total workforce. B.A./B.S. holders will comprise the majority of those with college degrees.

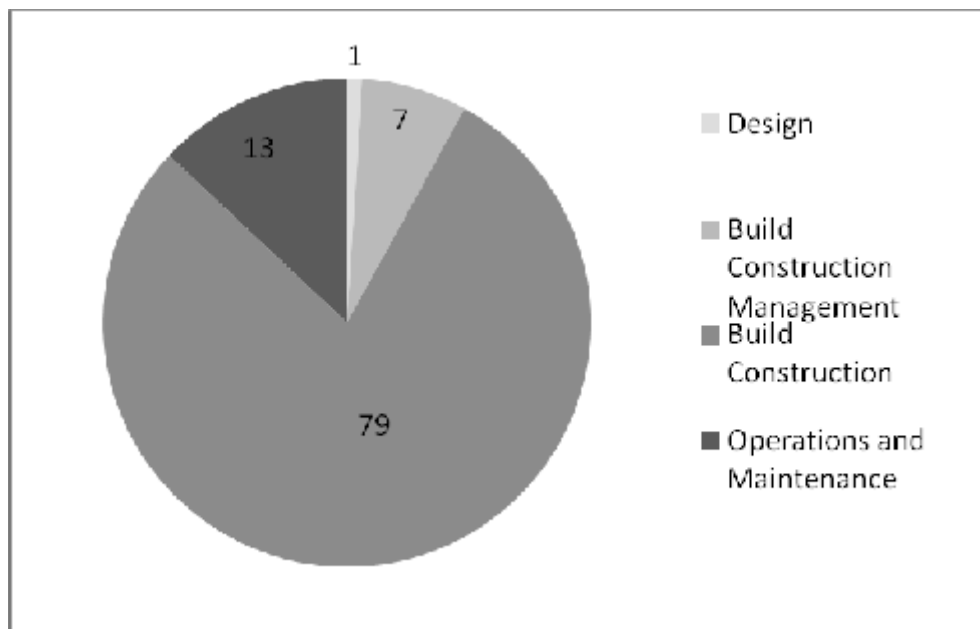


Figure 1. Total Personnel by Project Phase

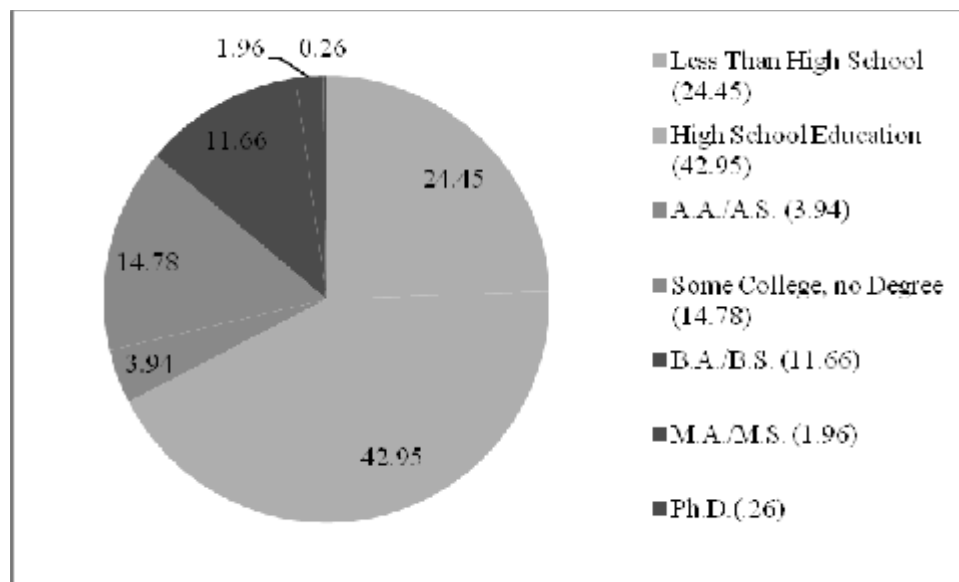


Figure 2. Total Personnel by Estimated Level of Education

Peak Period Personnel/Professional Needs

Based on the 2009 BP, we identify the 2013–2016 period as that which creates the most demand for professionals/personnel over the life of the project (see table 1). This coincides primarily with the build construction and the construction management phases, with smaller participation from design teams. At this peak period, the majority of the workforce will not require college degrees (i.e., ~71 to 75 percent will require high-school diploma or below), although many workers will require some college or an A.A./A.S. degree (16 to 19 percent). Significant numbers will nevertheless require four-year degrees or more (~6 to 12 percent).

Table 1. Peak Year(s), 2013-2016, CHSR Project

Year	Less Than High School	High School	A.A./ A.S.	Some College, No De-gree	B.A./ B.S.	M.A./ M.S.	PhD	Total
2013	11,500	18,857	1,286	5,510	4,387	473	64	42,077
2014	11,960	19,681	1,392	5,853	5,067	526	67	44,545
2015	12,402	20,483	1,450	6,813	4,762	535	68	46,513
2016	11,378	18,683	1,353	5,586	4,482	538	68	42,088

CAPACITY OF HSR WORKFORCE DEVELOPMENT

This section explains how the state of rail education in the United States is at best piecemeal and insufficient to meet even current needs.

Limited Capability in the United States to Teach Railroad Education

- Related to imminent HSR demand, no institution is responding on any significant scale to the need for instruction and/or research and development in the more specific field of HSR, and only a handful of college professors in the nation specialize in rail education. To the extent that it does exist, existing rail-related education in the United States is presently delivered by one or more of four limited mechanisms: (a) colleges and universities, (b) rail-industry-administered trainings, (c) fixed-location private rail academies featuring test railroads, and (d) independent “road shows” led by consultants.
- Overall, there are a few existing, extremely limited education mechanisms to conduct the needed HSR research and development as well as to teach curriculum.
- Very few railway engineering-specific courses falling under civil engineering degree programs exist; these programs are at best scarce compared to potentially impending HSR needs.
- There are a few relationships between several U.S. professors and professors of foreign research institutions to facilitate understanding of rail concepts (and HSR concepts), but these have not fully materialized.
- There are examples of regional cooperation in research (spearheaded by a regional University Transportation Center); however, few are HSR-specific.
- There are opportunities of collaboration with industry in offering specialized topics in short-course format at locations easily accessible to industry, but a regiment long-term curriculum has not been established for HSR matters.
- Collaboration with both industry and international partners in hosting rail conferences and facilitating contact and placement opportunities for students, however, only recently are engendering an environment through which to develop HSR-specific research.

The United States Is Behind in Rail Education Compared to that of Foreign Countries

- By contrast to the anemic U.S. national capability, in many European HSR nations, personnel requiring equivalent to certificate or A.A./A.S.-level training are often trained in trade school or “academy” settings.¹ In higher education, various other U.K. universities’ Civil Engineering and Transport Planning programs offer rail courses or course components. Most commonly, a university features one to three researchers who specialize in rail topics and lead PhD research projects in technical areas.
- In China, universities tout “Key Disciplines” at either the provincial or national level in areas such as “Road and Railway Engineering,” “Bridge and Tunnel Engineering,” and “Traffic and Transportation Planning and Management.” China offers Transportation Engineering degrees with Rail concentrations beginning at the

undergraduate level. Many of the railway universities in China are essentially owned and controlled by the Ministry of Railways.

- To prepare for the needs created by the development of HSR systems, the Taiwan High Speed Rail Corporation (THSRC) provided training to its engineers in managing HSR construction (specifically the importance of communicating more exact engineering specifications), and have dedicated HSR training programs, including the establishment of a Railway Technology Research Center.¹ This institution supports both education and training needs of the Taiwan HSR system.
- Japan and Korea, among others, maintain partnerships between government, universities and industry that train university students in HSR affairs.

In sum, the number and amount of existing university efforts directed at rail education are at best sparse in the United States, and those specifically directed at HSR are virtually non-existent, although some evidence of growth and development is available.

Overall, patterns of HSR workforce and workforce development demand as well as more specific needs for knowledge, information, and technology are demonstrated throughout this research. The statistical evidence demonstrates massive demand for personnel and professionals as well as their associated needs for education. A clear pattern of under-preparedness for this new workforce also is documented. Compared to HSR education systems abroad, the United States lags far behind. Similarly, California is unprepared to prepare the workforce needed to build its HSR system.

I. INTRODUCTION

This study assesses the overall employment, education, and training needs associated with building the California High-Speed Rail (CHSR) network. Given the high profile of national and state commitments to the project, a comprehensive analysis that discusses the education, training, and related needs that will be created during the build-out of the California HSR network is essential. By estimating the people power, skills, and knowledge required to complete the network, this report identifies the workforce development challenges that lie ahead in the build-out and eventual operation of the CHSR system. In addition, this report seeks to develop insight into how these challenges can be addressed by the California education system at all levels. The project is designed to explore the following questions:

- What are the types of workers required by the CHSR network at the various phases of the project's life over the next 15 years?
- How many of each type of employee are needed over the life of the project, and how do such estimates change over the life of the project?
- What are the specific skills and knowledge required by the CHSR workforce?
- What is the existing capacity for training and educating this workforce, and how must it adapt to the challenges posed at each stage of the CHSR?

Answers to these and related questions are explored to advance a firm understanding of the education needs of the CHSR network workforce, and to identify notable shortcomings in the existing workforce and education system that pertain to HSR matters.

CHSR AND LABOR IMPACT/LINKAGES

Relatively little existing literature has explored the linkage between creating HSR systems and identifying details of the workforce who will create it. As early as 1997, Haynes recognized that labor market considerations are implied by creation of HSR systems. Although existing research has identified the connection between the system and its economic implications, it has not directly identified the labor force requirements.²

More recently, Murakami and Cervero began to connect the existing alignment of the CHSR network with the existing markets and personnel/professionals surrounding those markets.³ They examined job and labor market profiles of 26 proposed HSR station-areas in California in 2002 and 2008, comparing them to experiences around Shinkansen HSR stations in Japan. The study showed that economic impacts concentrate in global cities, and found that increased density of jobs in knowledge industries had formed around stations (more so than control areas), suggesting that HSR can be more favorable to these particular types of industry sectors than to commercial/service sectors in general.⁴ However, these efforts do not directly identify specific job impacts associated with the CHSR network project delivery (e.g., design, build, operations, maintenance; DBOM), and does not identify high periods of demand for workers.

The Bay Area Council Economic Institute (BACEI) sought to identify the personnel needed to build the network. Its report states that by 2030, HSR will produce a sustained 1.1 percent increase in employment, or 48,000 new jobs in the Bay Area alone, and that construction

spending will directly and indirectly generate between 100,000 and 128,000 Bay Area jobs during the period of construction.⁵ Although BACEI did begin to look at regional impacts associated with the construction of the network, examining the impacts on the Bay Area region, detailed specification of the workforce composition was not directly explored, and further, no linkage was established to education and training needs of that workforce.

In Australia, Mahendran and Dockery⁶ as well as Mahendran, Dockery, and Affleck⁷ explored some of the workforce implications of rail and HSR development in that country. Generally, they identified workforce shortages created by the technical demands implied by HSR projects, noting "... that rail operations are becoming ever more knowledge intensive and increasingly dependent on technology transfer. Demographic workforce changes and technological developments, as well as changes to the labor force needs of operators within the rail sector have therefore heightened the need to improve training in order to meet the current and future skills needs of the industry and mitigate existing and emerging skill shortages." Although this research began to draw the connection specific to technology needs and workforce needs as well as their implications, their more specific findings are not particularly suited to California or other U.S. projects.

Most recently, the linkage between education and technological needs were explored by Chuang and Johnson (2011). Their research demonstrated the process of development of HSR in China, and provided preliminary evidence of the importance of the education and innovation practices in China on the development of an indigenous technological industry in the country.⁸ This research began to connect critical linkage between needs that are created during the complex build of HSR infrastructure in countries that newly adopt the systems, but it was absent of quantitative data that show the workforce demand created during HSR construction process, and it does not connect HSR workforce demand to specific education and training sector supply.

Thus, relatively little is known about the specific workforce impacts that the creation of HSR systems entails. Although there have been efforts to apply industry-standard rubrics (both as simple and more complex models) that provide a total estimated number of workers per amount of expenditure (reviewed later), such an approach fails to provide sufficiently specific information about the jobs and levels of education associated with the development of HSR networks. Further, the technological demands, and the training needs associated with those demands, have not adequately been identified; thus, there is even less known about the need to train and educate personnel in emerging technologies associated with the development of HSR systems. We seek to specify the number and types of personnel and professionals who will be responsible in the project delivery of the CHSR network, and to provide estimates of what training and education is needed for these workers. This question will be addressed both qualitatively—through the discussion of the technological challenges and associated needs—and quantitatively—through precision of vastly more specific estimates of job creation than have been developed to date.

WORKFORCE DEVELOPMENT AS A CRITICAL SYSTEM COMPONENT

President Obama identified the development of an HSR system in the United States as a critical challenge, with the potential to match the "space race" with the USSR in terms of economic benefits and technological development. In his 2011 State of the Union Address, the President stated:

Half a century ago, when the Soviets beat us into space with the launch of a satellite called Sputnik, we had no idea how we'd beat them to the moon. The science wasn't there yet. NASA didn't even exist. But after investing in better research and education, we didn't just surpass the Soviets; we unleashed a wave of innovation that created new industries and millions of new jobs... This is our generation's Sputnik moment. Two years ago, I said that we needed to reach a level of research and development we haven't seen since the height of the Space Race. In a few weeks, I will be sending a budget to Congress that helps us meet that goal. We'll invest in biomedical research, information technology, and especially clean energy technology—an investment that will strengthen our security, protect our planet, and create countless new jobs for our people.⁹

President Obama's speech represents a useful foundation for this research, as it evokes questions that frame the relevant issues of workforce development. Specifically, this research explores various ways in which build-out of the CHSR network has a series of identifiable impacts in the areas of knowledge, information, technology, and education and training needed to develop the system. Just as the race to the moon required major efforts to renew progress and expansion of American technology and people power, this research will explore how creation of an HSR system in California (and in other regions of the United States) places enormous demands in each of these areas. By identifying these demands, appropriate levels of response by universities and other institutions in educating and training California's workforce may be explored and clarified. Thus, we focus on four highly interrelated areas of need created by the build-out of the CHSR network infrastructure.

The Importance of Workforce Development

The most pressing workforce demand entails the creation of the massive HSR infrastructure that needs to be developed; it implies both immediate and longer term needs. To address these needs, professionals must be trained to address the entire HSR development process—from the earliest stages of design, through construction, and ultimately, operation and maintenance. Workforce development is intrinsically tied to the CHSR network build primarily because of the initial reasoning embodied behind developing the network. The system was proposed in part because it has the capacity to jump-start the California economy, insomuch as it buttresses the construction workforce with procurement bids. It also will inevitably have direct impact on industries outside of construction, including those associated with the design, operation, and maintenance of the network, through the infusion of technology into the system.

Supplementing the direct workforce required to construct the system, there will be a measurable indirect impact in the form of the supply chain needed to the existing workforce during the build process. This workforce will include the entry of technology providers to address the shortfalls associated with technological and knowledge gaps, and support management to indirectly maintain the services of the system. As noted by the Bay Area Council Economic Institute, there are notable business and commercial impacts: "Half of those jobs will be in service industries such as government, finance, real estate and insurance. Wholesale and retail trade, transportation, communication and utilities will account for approximately one-quarter of this anticipated growth."¹⁰

Role of the CHSR Association and the Development of the HSR Workforce

By design, the CHSR Authority (CHSRA) will remain relatively small in terms of the total personnel employed in the system during the project delivery phase. Thus, the bulk of training need will be shouldered by the California workforce through contracts with the CHSRA. The main obligation of the CHSRA will be to own the system, assure safety standards/compliance, monitor/administer contracts and agreements, manage right-of-way acquisition and assure environmental approvals are upheld, and related matters. To accomplish this, other aspects of the project, such as infrastructure delivery and system operations, will fall upon engineering companies, construction contractors, workers, equipment suppliers, technology providers, and so forth, which will need to be trained in the methods of delivering the HSR services.

Because the bulk of delivery of services therefore will be through providers (e.g., support industries, engineering companies, construction contractors, equipment suppliers, etc.), the dominant needs for training will fall upon firms, trades organizations, and the education infrastructure of California to administer training and to develop HSR specialized education. Specifically, training and education mechanisms will not be shouldered by the CHSRA, and assumingly will be administered by other parties. Concurrently, not all of the skills and education will be needed by the authority in-house, and training and education support more expectedly will be needed by these firms, contractors, and suppliers to train and educate their workforces.

The Demand for Training of HSR Personnel

CHSR personnel will need to be HSR-trained in a variety of new professional and personnel roles. Training upgrades will be mandatory for virtually all personnel associated with the operations and maintenance of the CHSR network, even assuming transfer of human capital to California from other countries. The workforce will be comprised of both new employees without a rail background as well as those retrained to HSR specifications, and demand will result due to the need for these employees to be trained in emerging HSR technologies, techniques, and methodologies.

Such a pattern of training and education need has been demonstrated in many foreign HSR models during the information and technology transfer process. The first operators of the Taiwan HSR line were from France and Germany (40 French, along with 13 German drivers, operate the trains, and the Taiwanese fleet of conductors was trained after the opening of the facility, over the next 18 months).¹¹ SYSTRA, a consulting firm with connections to the National Corporation of French Railways (SNCF) of France, has been a partner on the Korea Train Express (KTX) project since 1989. Its work has involved being the specialists who provide information to KTX related to civil engineering, track design, supervision of laying the track, pre-series trials, assistance with technology transfer, and auditing of the testing and launch process. Similarly, SNCF International has trained some 400 senior managers, engineers, and executives of the Korean Railways, demonstrating that Korea needed extensive support to acquire the right level of education and training to operate its HSR systems.¹² Although we have targeted the discussion specifically to a few firms for the sake of brevity, a plethora of providers and consulting entities have the capacity to sell the aforementioned training and education services to the CHSRA through any number of agreement types, including government-to-government or private firm contracts.

Nevertheless, in the recognition of the “California first” priority associated with the project, the mandates associated with “Buy America,” and the elevated interest in targeting the employment crisis in infrastructure-related workforces across the state, this research does not explore hiring foreign labor. Similarly, the Federal Railroad Administration (FRA) stated that it “believes that high-speed and intercity rail passenger equipment can and should be manufactured in the United States,”¹³ and that the “FRA will do everything it can to ensure that its grant funds are spent domestically, and where there is not currently domestic production, will do what it can to encourage domestic production.”¹⁴ Furthermore, individual states do have discretion to enact stricter “Buy America” policy under existing provisions which note that “any State may impose more stringent Buy America or buy national requirements than contained in section 165 of the Act and the regulations in this part”¹⁵ whereas non-compliance with Buy America policy must go through a more difficult waiver process, and if waived, encourages contract awards with the highest domestic content.¹⁶ Further, the FRA has affirmed the intention of using the Buy America mandate as a means to maximize job opportunities for American workers, stating a strict “Buy America” requirement ensures that U.S. manufacturers and workers receive the maximum economic benefits from this federal investment.¹⁷ Thus, our underlying assumption is to develop a climate in which CHSR will be constructed primarily with the domestic workforce, with emphasis placed on the California workforce, to help satisfy these requirements and preference.

The Planning Stages of Workforce Development in the CHSR

The CHSR Authority has generally recognized the need to train the emerging HSR professional fleet. It has released a preliminary design of the operations and maintenance personnel training that will occur before the startup of the Phase 1 HSR trains (through specialized HSR-specific training), written with explicit connection to FRA mandate. This training, scheduled to take place between 4 to 24 months (depending on the professional/personnel), will encompass in-classroom teachings as well as on-site “in the field” (i.e., on the railroad) for employees with no prior experience. On opening day of the CHSR network according to its current Phase 1 modeling, the CHSR system’s workforce will comprise an estimated 4,020–4,950 persons. This operations and maintenance phase will, of course, be implemented in accordance with demand for the positions; however, an employment need related to the delivery of key operations and maintenance services is expected as early as 2016–2017, with an attendant need to train the workforce in these specific positions.

However, this operations and maintenance workforce will not be needed until the 2019–2020 period (even later, according to new models), and it constitutes a much smaller number of employees than that associated with the design and construction of the system. The vast majority of the training and education required by the project precedes this period. As a result, personnel involved in the designing and construction phases of the CHSR project will have great training and education needs, with smaller and continuous training needs for personnel involved in the operations and maintenance of a functioning system.

Need for Appropriately Trained and Educated Workforce

The CHSR network will be a massive project implemented and completed roughly during the period of 2012–2033, using a process consisting of a standard DBOM sequence recognized in nearly all major HSR implementations as well as in similar large-scale, capital-intensive projects. This process will involve vast numbers of professionals already trained in specific trades and crafts as well as personnel who have been recently trained specifically to meet the demands of the CHSR system. Each part of the sequence will create a demand for various types of professionals and laborers. The details of these personnel and their required skills and training will be detailed later in this report.

Labor-demand changes over the life of the project are reflective of activities that need to be completed during that specific sequence. Project personnel/professionals will fall within four major categories of workforce for the CHSR system:

- Design Phase (engineering-oriented) personnel
- Build Management Phase (managerial) personnel
- Build Construction Phase (construction-oriented) personnel
- Operations and Maintenance Phase (multifaceted) personnel

These changes may be filled in different ways, including tapping the unemployed of groups of professionals/personnel as well as hiring individuals prepared by existing academic programs or recruiting from other sectors (when the position is more generalized). The project also implies a new form of labor demand, reflective of the technological and other forms of knowledge that must be obtained during the successful development of the CHSR network workforce.

Completing projects of this magnitude undisputedly creates vast opportunities in both traditional and new sectors of employment. However, to date, little is known about which precise types of positions—the types of education and training they require—are associated with a de novo build-out and implementation of an HSR system. We seek to identify specific jobs associated with the new technology and the training that needs to occur for these professionals to perform them. With as much detail possible, we provide estimates of the personnel associated with specific tasks, and recommend appropriate types and levels of education and training.

New Challenges to the HSR Workforce

Two major factors, the 220-mph speed frontier and the deployment of new HSR technologies, are closely linked to new workforce training and education needs. Simply stated, the challenge presented by the CHSR system is that it will be the first designed to travel at 220 mph in the United States. The closest approach to this speed in the United States was 170.8 mph (273.9 km/hr) in 1967, and although advancements in technology have been made in freight rail systems, less technological advancement in passenger service have occurred since this time period (primarily in the late 1970s). This report identifies that this 220-mph frontier has demonstrated challenges to countries that currently implement advanced HSR technologies, and presumably will pose immense pressure on the designers and builders of the California project because of the extensive list of unknown factors at

this range of speed. Furthermore, this limited understanding will seemingly have impacts on California and elsewhere. In California's current HSR network construction, the design team will be challenged to learn how to implement a vastly improved system.

The lack of completely reliable technology and knowledge to address the 220-mph frontier has been exemplified in countries that already have HSR networks. For example, the Chinese railway has announced plans to lower the speed of some HSR services in China amid lingering concerns over the safety and soundness of the rail network. According to recent reports, the Beijing-to-Shanghai HSR's speed will be lowered to 300 km/hr (186 mph), down from the original operating speed of 380 km/hr (236 mph).¹⁸ Practices related to train maintenance, system maintenance, or any number of operational symptoms have arisen and may force the trains to operate at slower speeds than their manufacturers originally envisioned. Thus, there are elements of the 220-mph barrier that pose challenges to emerging HSR countries, as the Chinese HSR experience suggests, for example.

The CHSR Technological Frontier

Another technological gap is that the CHSR network will utilize technology systems to operate the 220-mph network that are (a) fully purchased, (b) created from other technologies, (c) created specifically for the CHSR network, or (d) some combination of the above. Various national administrative departments and transportation organizations are currently identifying these technological gaps. At present, solicitations by the FRA are awarding grants to private-sector interests to develop technological research and development in a wide range of HSR-specific needs.¹⁹ The Department of Transportation,²⁰ the Federal Highway Administration, and the Transportation Research Board (TRB; a division of the National Research Council) also are actively soliciting private firms to develop technology systems and the next generation of smart transportation networks. These current efforts to solicit partnerships demonstrate the effort to identify technologies that will be critical elements of HSR systems.

CRITICAL AREAS OF HSR TECHNOLOGY

These HSR frontiers of speed and technology represent challenges for the California workforce during the development of the CHSR network. We further delineate the connection of education and training needs through noting the differences between conventional rail and HSR systems, connecting the increases in technological need with specific education and training needs. There are many notable differences between conventional passenger rail and advanced HSR networks. Six major factors stand out as having the most influence on the development of HSR system technologies. Specific technologies that will need to be built into the future CHSR network to address these challenges are discussed next; each implies significant training and/or education requirements for the emerging HSR workforce.

Factor One: Addressing Noise and Vibration

Beyond the 150- to 165-mph range, the HSR systems undergo important physical changes. As a natural process of physics, noise and vibration of the rolling stock becomes a significant factor. Technology in design and construction of HSR systems must account for those characteristics and deploy mitigation technology that addresses the noise factors.

Literature associated with the increase in speed and the relationship to the increases in noise and vibration has been extensive.²¹ Noise and vibration from HSR trains are emitted from the wheels, the contact with the rail, the sleepers (the rectangular object that supports the railroad tracks), and through aerodynamic interaction while traveling at high speeds.²² The point of contact for the electrical wiring to the overhead line also is a primary area of noise emission. Lombaert et al. (while discussing the HSR) noted that issues related to ground-borne vibrations are extensive, and that factors can be mitigated with certain technologies.²³ These technologies disperse noise through the track structure, including the rails, sleepers, ballast, and sub-layers, and propagate as waves through the surrounding soil.²⁴ Beyond 185-mph, the primary system emitting noise is the pantograph (overhead wiring contact) with an acoustic pressure level of 83.0 dB.²⁵ Extensive knowledge exists regarding the technology to address HSR noise and vibration, particularly in Japan. Currently, FRA officials are deciding how HSR will be regulated and whether HSR trains will need to be in compliance with noise-emission standards for interstate railroads issued by the Environmental Protection Agency and pursuant to the Noise Control Act of 1972.²⁶

Technological Impacts on Existing Education and Trades Systems in California

Noise, vibration (and resulting wear), and settlement (the “sinking” of track into the ground) are factors that need to be addressed through the implementation of technologies that are in compliance with existing policy to control noise, many of which we have not previously deployed to address these concerns. At colleges and universities, fields of research and technology around this development will be connected to disciplines such as engineering, engineering design, engineering physics, engineering science, aerodynamics engineering, materials engineering, traditional engineering, and all aspects related to the engineering design of systems in the CHSR project. In addition, non-scientific disciplines such as urban planning/design also may be enlisted to address these issues (for barrier design, or planning related to how building construction can be utilized, etc.). Given the comparatively limited research and prototype development related to systems of sound and vibration mitigation, the university will be a prime area of research and development opportunity.

Once designed, the trades will be challenged with the construction of massive elements related to noise and sound vibration, including new methods of training around slab track construction, the use of new concrete and rebar materials, and training related to the use of new, prefabricated structures that prevent settling and other noise- and vibration-connected elements. The CHSRA has planned the use of prefabricated segments or rolling forms in standard superstructure cross sections.²⁷ There will be an anticipated demand for HSR-specific training related to the effort of the CHSRA to deploy new prefabrication techniques. New efficiencies related to aluminum fabrication and construction for welders specialized in aluminum will be needed, at high levels of efficiency and detail with respect to the building of HSR rolling stock (Aluminum fabrication/manipulation is an ultra-skilled labor activity). There will be a demand related to trades training with respect to the new methods of construction as well as attention to specialized fabrication technique.

Factor Two: Use of Advanced Train Control/Signaling/Collision Prevention

Train control, signaling, and collision-prevention systems are major challenges faced by HSR systems operating at higher speeds. One of these challenges for the development

of the CHSR will be the implementation of a communication network that encompasses emerging Positive Train Control (PTC) systems, which is characterized by complex signaling practices and networks of communication, advanced collision control, and other safety mechanisms. PTC systems are integrated command, control, communications, and information systems for controlling train movements with safety, security, precision, and efficiency.²⁸ Safe and efficient operation of an HSR system depends primarily on the performance of its Automatic Train Control (ATC) systems via the interaction of the train with the network around it. Federal law requires passenger and major freight railroads to install PTC on most major routes by the end of 2015.

The basic functions of this system include enforcing all speed limits on a train to prevent speeding through curves, switches, work zones, and other features that require speed supervision and enforcement to ensure safe operation. Second, the systems will be designed to ensure that trains are separated to avoid rear-end and side-swipe collisions. Finally, prevention of derailments and collisions from movements through incorrectly set and/or unlocked switches and from conflicting train movements by setting and locking switched routes will be achieved through interlocking that will control train movements within a safe parameter.²⁹ Digital data radio communications systems, wayside and onboard computers, and automatic positioning systems will be major components of the system.

Current Status of PTC Systems

Many options are associated with implementation of various levels of HSR PTC systems. These monitoring systems will require analysis and operational update of the network in real time through computerized systems that monitor and manage the complex matrix of information associated with 220-mph HSR practices.

Current PTC systems manage pre-existing (albeit much slower and less efficient) HSR networks in the United States. The Northeast Corridor currently has implemented a technology system for monitoring train control communications that include ENSCO-provided (i.e., purchased) autonomous systems to monitor the interaction between vehicle and track with the launch of Amtrak's Autonomous Ride Monitoring Systems on its Acela high-speed trainsets.³⁰ This system also involves GPS, wireless communications capabilities, central processing servers with data processing, Database Management System, and Geographic Information Systems (GIS) applications, and communication links between the onboard units, the central processing servers, and the data recipients. These kinds of technologies will be integral to the implementation of the future platforms of PTC for the CHSR.

The CSHRA Program Management Team has indicated that ATC systems will be developed in the delivery of the CHSR network. It reportedly will include the functions of PTC to meet the objectives of PTC as defined by the Rail Safety Improvement Act of 2008 (RSIA). For the CHSR system, PTC shall be an integrated set of functions within the ATC system where train collision and over-speed protection as well as the protection of roadway workers shall be enforced. Although many "PTC" systems are being implemented as overlays on conventional wayside signal systems to meet the RSIA deadline of the end of 2015, PTC for the California HSR will be an integral part of the ATC system.³¹ Further, given the emerging "layering" technique of constructing the CHSR and the mandate across rail

sectors to develop PTC systems, there is a particularly complex set of issues connected to the fact that Caltrain and Metrolink may adopt different types of PTC from that preferred by HSR. This may lead to the management of multiple PTC systems, which increases the complexity of a fully integrated network.

Overall, PTC systems are characterized by technology with the capacity to produce real-time, complex systems analysis specifically related to positioning of HSR trains. These systems function to link information that is communicated to and from the HSR train to the conductor in the cabin. These systems are categorized by the participation of onboard computer systems that monitor and report the status of HSR trains in an advanced communication network. Furthermore, creating the correct informational flow and the type of information to provide to the conductor remains central. Although preliminary observation of higher speed locomotives and the interaction between cab and driver have been researched by the FRA³² through observing foreign HSR design setup, further development of the systems that will be part of the PTC system, the design and setup of the CHSR cockpit, and the overall informational network design for the 220-mph system remains in the preliminary design phase for California system. This clearly demonstrates a challenge to the development of the system, and effective train control systems will need to be deployed to execute the CHSR network.

Although PTC technology is emerging, it is still in preliminary deployment amid the backdrop of a deteriorating rail infrastructure pertaining to communication systems. The effectiveness of these systems in other rail environments has deteriorated over time, as documented in a self-assessment of the rail infrastructure conducted by the Federal Transit Administration (FTA).³³ Moreover, the U.S. Government Accountability Office (GAO) has expressed concern with the technological and knowledge needs that must be maintained during the construction of the national high-speed rail network. Specifically, the GAO has noted that the PTC systems software needed to test and operate these components remains under development, which may impact the availability of components when needed and could create subsequent delays in testing and installing PTC equipment.³⁴ As a result, pressure is growing to complete the complex, previously untested systems in future PTC HSR systems within a limited timeframe. As a result, there are emerging challenges that will have to be met by the universities and trades to prepare to design and implement the PTC system.

Workforce Development Impacts of PTC

Universities and trades will be challenged to supply the workforce needed to implement modern PTC systems amid declining technological capacity in this area and growing concern about the time frame of delivery of PTC. They will be challenged with the need to design and construct technologies related to sensory and computerized networks and their cross communication, including technology design in automatic train operation, automatic train supervision, technology of the signaling and controlling system, communication system design, collision mitigation design for HSR rolling stock, fire mitigation design, derailment mitigation design, ATC system, and a centralized train control center that includes microprocessor-based systems, digital communications, commercial off-the-shelf systems, and performance-based rule-making technologies. This need has been recognized by the Department of Transportation, Research and Innovative Technologies Administration, and some of the technologies are currently under development.³⁵

For universities, this translates into demand in the fields associated with the development of computer intelligence (hardware and software design), design of the associated algorithms and mathematical platforms that manage the PTC systems, and design of technical field-ready components of these computerized systems. Many of these systems will be implemented for the first time as a PTC variant. Consequently, trades workers will be needed to support the placement of the technologies in the field, including those with HSR certification (and perhaps further accreditation) in Telecommunications, Technology, Technician, Electrical and Electronic Engineering Technologies and Technicians, that will be involved in the deployment of PTC systems.

Factor Three: Acceleration and Deceleration Characteristics

Managing the electrical systems needed to power HSR systems (and managing the general electrical grid impacts) poses the third challenge. Previously, HSR velocity has been achieved using diesel as well as overhead electrification. However, in the future, most—if not all—HSR systems will use overhead catenary electrification lines (OCL) as the means to continuously achieve these speeds. Most parts of the American rail network are not electrified with OCL, with the Acela in the Northeast (Washington to Boston) an exception. Consequently, the technology of this level of electrification poses a challenge to the development of the CHSR network, as new demands on the electrical grid are anticipated to challenge its deployment.

The acceleration and deceleration of high-speed rolling stock to high speeds is comprised of key technology systems. For the CHSRA, as reported in technical memorandum, mandated testing procedures require that each train achieve a test speed greater than the in-revenue service operating speed—that is, between 223-mph (minimum) and 242-mph (recommended/preferred)—and that this speed be sustained for a duration of ten minutes for each test run.³⁶ Key technological systems required to achieve this goal may include the next generation of synchronous 3-phase alternating current traction motor systems, the electrification and traction power systems associated with the motor system, overhead contact systems, OCL, and traction power supply stations.

The State of National Traction Power Systems

At this time, the CHSRA is committed to create the world's first system with a zero-carbon footprint, with its power being provided through wind or solar energy, thus helping to minimize air pollution and smog throughout California. But full design of this “grid independence” has not been fully developed.³⁷ To comply with this goal, management of the OCL and other electrification components of the CHSR network system require developing electrified grids with the capability to accelerate trains to the 220-mph capacity, which is an emerging electrical and managerial challenge. These personnel and professionals will be challenged to design and manage the deployment of emerging solar, wind, and other renewable energy technological capabilities, in alignment with emerging energy management policies and practices.

This commitment is against the backdrop of a relatively dormant, if not decreasing, traction power/electrification system. The FTA also assessed national traction powered systems in American rail networks from 1997 to 2006, and has identified a deteriorating trend in these systems. Overall, this poses a challenge to implement the modernized Traction Power Systems needed in the CHSR network. Specific to HSR, to date, the Program

Management Team has moved forward with the design technical memorandum of the CHSR traction power system, and this memorandum provides only a review of standards and best practices for the overhead contact system requirements.³⁸

Workforce Development Impacts of HSR Electrical Systems and Energy Management

The higher education system is thus *challenged* to support the design of advanced energy-producing systems and networks, including technology design in traction systems, power systems, propulsion system variations, braking systems, electrification networks, power distribution networks, catenary system design, and pantograph electrical design. Universities may be called upon to design the Electric Multiple Unit systems; they will be further challenged to design technology for efficient storage of regenerative electric power, highly efficient batteries with an ultra-long life and associated control techniques, and other systems to optimize electrification of the CHSR network. The need to modernize the electrical grid in California and to properly manage and distribute the emergent electrical demands created by the propulsion systems of the future CHSR network places additional demand on education institutions, including electrical and computer engineering programs at the B.A./B.S. level.

Trade laborers will need to be able to support the placement of technologies in the field, including certification (and possible further education) in telecommunications, technology, electrical and electronic engineering technologies and technicians, that prepare for the trades to have the capacity to implement new construction methodologies related to the electrification and power distribution process. This includes training in the proper and precise tension across the OCL and other systems as well as all affiliated contact points. The technicians involved with the braking system will require extensive specialized training in electrically controlled braking and other aspects of the traction process to assure proper capacity to stop the train within specified and precise parameters. As a result, we may see a demand for trades related to the electrical construction and maintenance process of these HSR systems and sub-systems.

Factor Four: Comprehensive Communications Network/Monitoring (HSR Central Command)

Central control communication systems are paramount to the successful operation of 220-mph train speeds in California. The central control systems' computerized process functions as the brain for the overlapping operational and communication platforms for the HSR network. At decreased speeds, including the 120- to 160-mph range, these systems are important to assure operational efficiencies (in controlling train communication) and to prevent accidents from occurring. With increases in speed come increases in the precision needed in the computerized brain systems. In China, the operation safety supervision system is comprised of a series of monitoring systems that are highlighted next. These systems run through a centralized monitoring system. There are four major communication channels of these monitoring systems,³⁹ including communication from both train-based and ground-based systems:

Currently, the United States does not have the capability to link the systems through a centralized brain for HSR systems at the level required for systems traveling at 220-

mph, posing a major technological challenge. In preliminary design, the CHSR Program Management Team is currently developing a memorandum that outlines the characteristics of the future CHSR network control center.⁴⁰

Workforce Development Impacts of Communications Systems

An extremely complex system is thus required, with the capability to fully address factors such as systems integration, artificial intelligence to sift through information, and capacity to fend off system threats. Central control will have to be linked to the field through a complex network of new and advanced technology sensors and communication platforms. The design of central control will have direct impact on universities through the need to develop affiliated systems and train designer/manufacturers related to automatic train supervision, communication, operations, a centralized train control center, communication systems analysis, installation of a system-wide communication system, central/local controls, and communications system properties. This translates into the need for enhanced capacity in the fields associated with computer intelligence, hardware and software design, design of the associated algorithms and mathematical platforms that manage the systems, and design of technical field-ready components of the system. For universities, this likely translates into some role of research and development in the areas of electrical and computer engineering, electrical engineering, and computer sciences. These research facilities may be challenged with the demands associated with the creation of these systems and sub-systems.

After the design of the new communication systems, the communications technology will be constructed and maintained in the field. This translates to technical training needed in areas such as telecommunications, electrical and electronic engineering technologies, and other related technical industries. Trades will be challenged with the technical upkeep of the systems, and will play a critical role as technicians in the CHSR network both in the build construction and the maintenance phases. Trade employees will require training that targets proper handling of these technologies, including precise placement, and the understanding of the upkeep of these communication systems.

Factor Five: Intrusion Prevention and Detection and Natural Disaster Detection

As HSR trains reach 220-mph, intrusion detection on rail rights-of-way becomes paramount. At this speed, objects in the path of the HSR train naturally pose higher risk to the passengers and surrounding area. Debris and other objects on the track can severely damage rolling stock at this operation speed.

Intrusion protection in the Japanese HSR model is achieved through designated track alignments, which are elevated away from most obstructions, as well as advanced detection equipment in areas designated as points of concern (including entry and exit points of tunnels, and at stations), especially related to earthquakes and other natural disasters. For all trains, the main area of concern remains the tunnel entry and exit points due to falling rock or other debris. The Taiwan HSR network is noted for these advanced safety-monitoring devices for earthquakes, high winds, storms, rock falls, and potential derailments, all of which were modeled after those purchased from their Japanese firm supplier.

HSR systems need to be designed and built to protect against possible natural disasters, including floods, strong winds, heavy rainfall, landslides, rock fall, heavy snow, and avalanches, and especially earthquakes in California. Second, protective measures must be installed in special areas along the line. These measures include wind barriers, slope protections, rock-fall protections, avalanche protections, and derailment walls. The third system is the installation of a natural disaster warning system: A modern HSR must be a closed system with a well-instrumented monitoring and warning system. These systems include monitoring and automatic warning functions for nature disasters and human intrusions, including personnel and vehicular intrusions. To address this, the CHSRA has recognized the need for integrated safety in the CHSR network build.

Earthquake Detection Capability

Comparable earthquake safeguards are observed in Asia. These systems also are seen in earthquake detection capacity, currently in the Taiwanese, Chinese, Japanese, and Korean systems. The TERRA S system functioned to stop Shinkansen bullet trains during the extremely destructive March 11th, 2011 earthquake in Japan. The Korean earthquake monitoring system was integrated in 2002. Since then, the Korea Integrated Seismic System has been playing the main role in real-time seismic data exchange between different seismic networks operated by four earthquake monitoring institutes.⁴¹ Similar integration with such detection systems is required in the CHSR network.

In sum, as trains attain high speeds, technology that senses concerns outside of visual inspection become more important. Generally, the monitoring systems will have to operate faster and more accurately identify threats and intrusion. This is observed in the continuous technological-upgrade process, in the TERRA-S system, the Taiwan network-monitoring systems, and other systems of monitoring within all HSR systems, which have varied levels of system implementation. These systems have been recognized by the developers of the CHSR network; as a result, systems planning currently incorporates these elements.

Workforce Development Impacts of Intrusion Protection Systems

To construct the complex monitoring and detection system, an extensive network of communications and sensory technology will need to be developed for the CHSR network. This translates into workforce demands related to systems that will be involved in Automatic Train Protection comprehensive sensory networks, disaster warning systems across bridges, overpasses, and other crossing locations. This technology further will include detection at key points, through the use of tunnel intrusion-detection systems, including earthquake detection, high wind, heavy rainfall, flood, fog, landslide, broken rail, vehicular intrusion, and rock fall triggers and safeguards.

For the university, the challenge is to develop faculty and students in the areas of sensory technology, involving the fields of engineering mechanics, engineering design, and other disciplines related to the creation, design, and preparation of prototype of the sensory network as discussed. For trades, this translates to the training necessary to implement the aforementioned sensory systems, which will be either prefabricated or require more complex assembly. Training will be required to assure proper functionality and precise deployment of these systems. Technician training will be required to assure that the workforce has the necessary training level for proper functioning of the sensory systems.

As shown earlier, the technology related to the deployment of intrusion protection and other monitoring systems has high potential to challenge both the university and trades in design and deployment.

Factor Six: Maintenance of Systems and Maintenance of Rolling Stock

As speeds increase to the 220-mph frontier, maintenance and assurance that systems are operating within precise parameters become paramount. At these speeds, factors such as wear and tear increase the likelihood of accidents. As a result, maintenance practices and related technologies are demanded to conduct routine maintenance within emerging HSR mandates and to identify and mitigate issues that arise as the system goes into operation.

Maintenance-of-way Technical Procedures

Maintenance-of-way procedures are critical to the safe operation of the CHSR. Major Maintenance-of-way challenges for trains traveling at 220-mph include a new level of precision that is associated with the design and construction of HSR tracks, with new technological advancements in track systems: In recognition of the new interaction between rolling stock and track/systems at the higher tolerances of speed, all systems will require critical and precise maintenance processes to assure proper operation of the HSR network.

HSR thus creates the need for a complex maintenance process. The challenge is to design and construct a track system that provides the required track geometry for future high-speed passenger trains traveling up to 220-mph and the strength to withstand repeated heavy axle loads from HSR trains. Thus, maintenance practices will have to address HSR wear processes appropriately to prevent the potential for systems to wear in ways not intended by the designers. As the speed of the rolling stock is increased, the factors of maintenance become more important.⁴²

Further, The FRA Office of Research and Development's Track and Structures Program sponsored a study for developing and testing a rail defect-detection system based on ultrasonic guided waves and non-contact probing. Current rail defect-detection systems based on ultrasonic testing have limitations in terms of reliability of defect detection, inspection speed, and other drawbacks associated with the requirement for contact between the ultrasonic probes and the rail surface. More importantly, conventional ultrasonic testing of rails has serious difficulties detecting internal defects in the presence of surface shelling.

The rail defect-detection technique that is being funded is based on fundamentally new concepts that (a) use ultrasonic waves traveling along, rather than across, the rail running direction, (b) use non-contact means of generating and detecting the ultrasonic waves in the rail, and (c) use advanced signal-processing algorithms to de-noise the measurements and extract robust defect-sensitive information. A prototype is being assembled based on this technology, and plans are in place to install and test the prototype in the FRA Research Car.⁴³ Overall, the need for railroad maintenance technology and advanced maintenance practices connotes demands for HSR training and education.

Maintenance practices have to be schedule-oriented as well as proactive in identifying potential issues that arise in 220-mph train operation. These maintenance practices comprise a three-tiered process: basic maintenance, moderate maintenance, and comprehensive

overhaul.⁴⁴ The main activities associated with HSR rolling stock maintenance include preventive maintenance, corrective maintenance, technical assistance en route, wheel re-profiling, ultrasonic tests, modifications, and other activities scheduled within the operational cycle. Various firms (including Japan Rail and the SNCF) have assisted CHSR management in this regard; however, the specific trainset technology for California HSR has not been selected, limiting the usefulness of such efforts.⁴⁵

Maintenance of HSR Rolling Stock

Overall, the process as described earlier entails four different levels of involvement with respect to HSR maintenance. The challenge in this process arises as knowledge and information related to these processes, especially at the 220-mph range, are developed and recognized. HSR car inspectors are responsible as the first line of defense, associated with identifying patterns of wear, damages associated with HSR rolling stock (e.g., damage caused by striking debris at 220-mph). They will have to be knowledgeable of all major factors associated with trains traveling at such high velocity.⁴⁶ Because of this increase in sensitivity to the precision associated with the mechanical parts of the HSR rolling stock, the next level of attention to cleaning, inspection, repair, and maintenance will be a priority for the successful implementation of the CHSR project.

Some countries that have adopted HSR systems have received support quickly in this regard, as compared to other operators. In Spain, for example, the SNCF designed and led maintenance operations over a two-year period. The SNCF also assisted South Korea in selecting and inspecting high-speed rolling stock and trained some 400 senior managers, engineers, and executives in a broad range of skills such as signaling, catenaries, track, rolling stock maintenance, HSR operation, safety management, marketing, and passenger information systems. SNCF experts continue to assist Korea in maintaining its high-speed infrastructure. The Taiwan HSR system receives similar support from Kawasaki (providers of the 700T Shinkansen trainset), who maintain the trains under contract with Kawasaki.

Workforce Development Impacts Related to Maintenance

Trainers and educators will be challenged with both traditional (i.e., conventional rail) and modern methods of addressing maintenance practices related to the HSR rolling stock. Traditional maintenance will be conducted within the mandates currently under review at the FRA [and developing the American Railway Engineering and Maintenance-of-Way Association (AREMA) protocol] as outlined earlier, modifying existing maintenance practice to be able to respond to HSR rolling stock needs. As a result, trades will be challenged with new timetables of maintenance as well as new methods of problem identification, potentially through specialized technology training that assists in the identification of non-superficial maintenance issues.

Specifically, further practices will involve the use of advanced identification of system maintenance concerns through sensors, computers, and use of sonic vibration detection. This will result in the deployment of advanced technology to assist in the maintenance process related to track works, bridge, viaducts, earthworks, station maintenance, maintenance bases, geometry design, ballasted or slab track, turnouts and crossovers, maintenance of power/signaling and controlling/communication/wayside systems, maintenance of track works, and storage yards. Universities will be challenged to train and educate professionals who can design and deploy such systems.

Summary of Six Areas of Technological Challenge

We have identified six different areas of rail technology that are inherently different between HSR systems and standard passenger systems. The major contributing factor is the higher speed, which increases the complexity of the HSR train services and associated technologies. The 220-mph range is a frontier of sorts, at which the understanding of the following factors becomes paramount. The first factor associated with running trains at 220-mph is the emitted sound and vibration that they will create. The second factor involves the onboard train communication systems—cabin to control, control to control, and cabin to cabin—all of which are conducted through a centralized ATC system. Factor three concerns the comprehensive and integrated systems needed to power the train at 220-mph. The fourth factor is the necessity of a centralized communication “brain.” The fifth factor is the network to monitor for threat and intrusion. Factor six addresses the extensive maintenance which must take place to operate the HSR trains efficiently during 220-mph service, for rolling stock and infrastructure.

DATA AND METHODS USED IN THIS STUDY

We generate an inventory of the workforce needs that will be created by constructing the CHSR system. To do this, we estimate as accurately as possible the size and characteristics of workforce needed for this system. We analyze this workforce over each of the key phases of project delivery, including the design, build (and build management), operations, and maintenance phases, and highlight the workforce characteristics of each phase. Our approach differs significantly from the widely utilized “top-down” methodology used by researchers to estimate general workforce impacts, which provide broader estimates of labor need that are void of more specific workforce characteristics.

“Top-down” methodology refers to the standard way policy analysts and researchers assess personnel-to-expenditure ratios in large infrastructure projects when creating estimates of the total workforce needed to complete a large project. Typically, a measure of a given ratio of job-years created per \$1 billion of infrastructure spending is used to create such estimates, as represented by extensive use of this measurement by notable transportation associations. For example, the American Public Transportation Association (APTA) and the American Association of State Highway and Transportation Officials (AASHTO) use similar approaches.⁴⁷ Other research that has estimated employment from construction projects also has relied upon job-years-to-expenditure ratios, including the United States Conference of Mayors, which used a job-years-to-expenditure metric with respect to anticipated increases in city gross regional product.⁴⁸

Such estimates are typically derived from another type of modeling known as IMPLAN Input-Output modeling, in which cost estimation is applied to estimates of total personnel, where cost and spending employ specific types of personnel/professionals. IMPLAN modeling is a more complex modeling technique that has been modified for use in the top-down methodology by policy analysts and researchers; however, when applied as a general metric, it cannot yield the specific workforce needs of a particular infrastructure project.

In contrast to the prevailing methods, our estimates for the CHSR workforce are based on the creation of a bottom-up measurement, in which we organize the 13 key data elements briefly outlined in table 2, to depict a detailed representation of the workforce by project

delivery phase (DBOM). This, in essence, is the reverse-engineering of cost-estimation data to examine the labor elements needed over the life of the project, by identifying what labor is needed, in each of the four project phases. This analysis determines that project personnel/professionals fall within four major categories of the DBOM work cycle, and measures PY projections according to the following four phases:

- Design phase (engineering-oriented) personnel
- Build Management phase (managerial) personnel
- Build Construction phase (construction-oriented) personnel
- Operations and maintenance phase (multi-faceted) personnel

Table 2. Summary of Data Used to Measure the CHSR Workforce, by Phase

Data and Information Used	Design	Build Management	Build Construction	Operations and Maintenance
CHSR Network Cost Estimates	X	X	X	X
Technical Memorandum Provided by CHSRA, Program Management	X	X	X	X
Program Management Team Size/Type Measurements	X	X		
Rolling Stock Personnel/Professional Estimates	X	X		
Rolling Stock Design and Build Time Frame	X	X		
Variable Cost Personnel Estimates	X	X		
Independent GIS Estimation of the CHSRA Network, Phase 1			X	X
Unit Price Details			X	
Crew Report, Unit Price Elements			X	
Tunnel Cost Estimation			X	
Labor Composition Data			X	
Operations and Maintenance Projections				X
Foreign Operations and Maintenance Projections				X

We identified connections between these elements and cost, time, labor (over time), labor composition, total needs of systems construction, and similar linkages. Based on these elements and the availability of data in each phase of the project, we used three major methods of measuring the workforce:

- Design and construction management phases: We estimated the design phase and the construction management sub-phase with more traditional “top-down” cost estimators as a base.

- Build construction phase: The build management phase, by far the longest and most expensive phase of the project, is measured in the same manner as that using the complex, bottom-up methodology.
- Operations and maintenance phase: This phase is measured using comparative statistics from the CSHRA and other nations.

Overall, this methodology provides highly detailed estimates of the workforce needed over the life of the CHSR project that were organized to represent direct labor needs during each phase of the project (see Appendix A for an extended explanation of the data used to estimate and measure the CHSR workforce).

CHSR Education and Training Index

The next critical step was to supplement the estimates of workforce size and types of positions with education and training impacts. To do this, we designed a comparative index titled the “California High-Speed Rail Education and Training Index.” This was derived from multiple data sources, including the U.S. Department of Labor, Employment and Training Administration, O*NET data, Employment Development Department, Department of Labor, Bureau of Labor Statistics, and EMSI (Economic Modeling Specialists Inc.) Data. These sources helped us to estimate with some confidence the level of education needed to hold a given position on the HSR workforce.

The index is a comprehensive list of the education and training by degree level expected to be attained by each type of worker required for the CHSR workforce, over the period of 2010–2025, for the 256,000 direct professionals/PY identified as necessary to complete the project based on the 2009 Business Plan (BP) modeling.

Our research focuses on direct workforce needs, as opposed to the total workforce needs (which include indirect and induced labor), as these levels of workforce are not observable in the direct tasks and activities needed to complete the project. However, this analysis does *not* reject the more inclusive workforce projections of the CSHRA 2009 and 2012 BPs. Instead, the bottom-up methodology used in this research more accurately identifies the direct labor needs of the CHSR project. We outline other caveats pertaining to our methods of estimating labor (and its impacts) in Appendix B.

Bottom-up Estimates as a Process Flow

The more complex estimation techniques used for the bottom-up build phase estimation warrant detailed discussion.

The steps illustrated in figure 3 are:

Step 1. Set a benchmark of the direct personnel that we anticipate being able to measure, which limits the amount of total direct labor that can be used over the life of the project.

Step 2. Obtain cost estimation data, and adjust it to be able to measure labor, by mile.

Step 3. Measure a detailed CHSR route, based on the 2009 BP Rote Modeling.

Step 4. Design a set of per-mile, per-element measurements based on defined CHSR elements outlined by the Program Management Team.

Step 5. Adjust the labor model to time frame needed to deliver project.

Step 6. Adjust the total PY estimate, by element, over the life of the project.

The output (depicted as a star) confirms our detailed personnel estimates against benchmarked personnel ratios, which will be discussed in the introduction of the next section.

These estimation steps are illustrated as a sequence map as depicted in figure 3. The white arrows in the figure represent steps taken, and the black lines represent the outputs from each step. The final step (indicated with a star) is the comparison of the benchmarked top-down estimated workforce (from Step 1) to the more robust and detailed analysis of the bottom-up measurement (from Step 6) to analyze the accuracy of the estimate. The output confirms that our bottom-up labor estimate is within acceptable original benchmarked ratios while also providing a wealth of project workforce details.

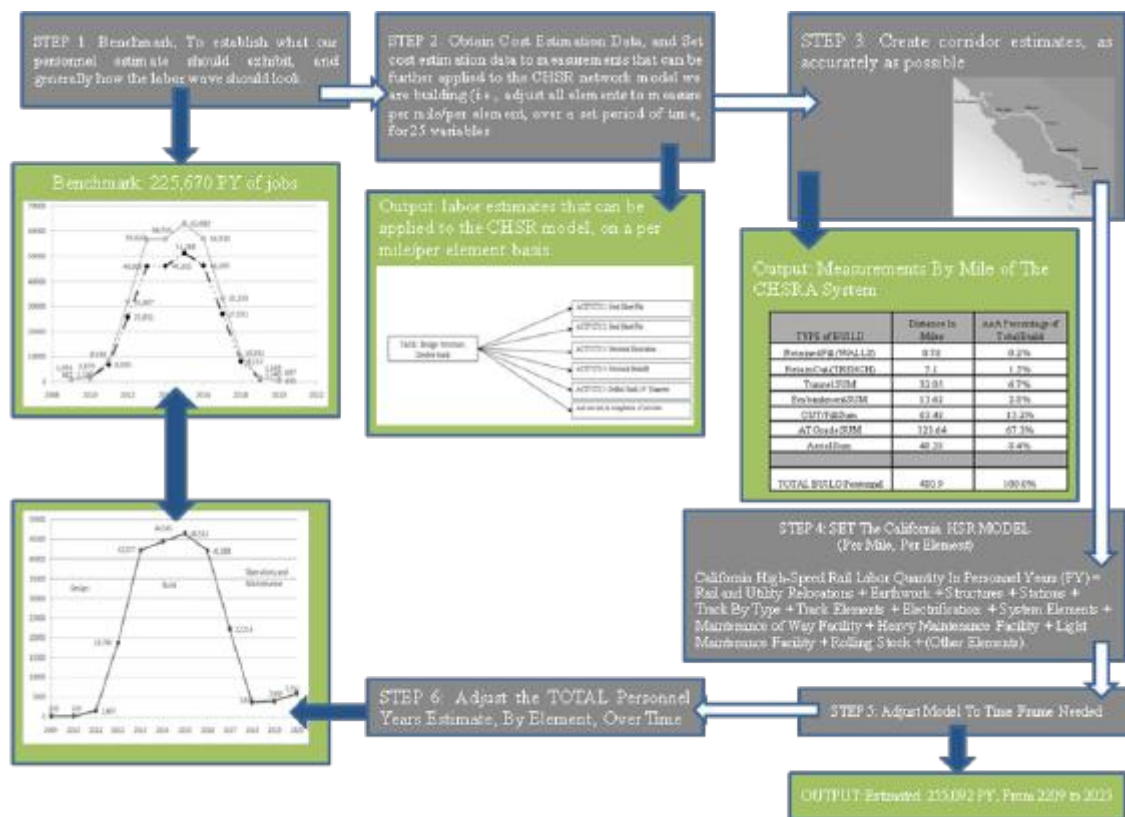


Figure 3. Bottom-up Estimation as a Process Flow

Thus, to arrive at personnel estimates over the life of the project, a complex analysis within benchmarked parameters as set by the CHSRA was conducted by means of an independent model that analyzes the workforce composition. This was achieved through the separating of the project delivery into four phases (DBOM), and conducting bottom-up estimation whenever possible. The most complex bottom-up analysis was conducted for the build phase, which represents the largest demand for labor. After accepting the estimates within benchmarked ratios, the data have been attached to anticipated level of education through the compiled index. This, in turn, created the extensive education and workforce data that are described in the following section.

II. ESTIMATES OF EMPLOYMENT AND WORKFORCE DEVELOPMENT

INTRODUCTION

Using the personnel bottom-up estimation modeling that we described earlier, we have compiled a comprehensive list of the direct personnel needed to design, build, operate and maintain the CHSR network. This section provides an overview of our estimates of jobs (measured in PY) and links them to the types of education and training needed to support those jobs. We also present the changing characteristics of personnel over the life of the project, with estimates pegged to each sequence of project development. We place particular emphasis on peak periods of employment and workforce development needs to highlight the connection between quantitative and qualitative demands created over the project delivery process.

EMPLOYMENT ESTIMATES SUMMARY

Peak Period Characteristics

According to both traditional mathematical models and the more inclusive bottom-up approach used here, the peak period of workforce demand will occur (approximately) during the years of 2013–2016, based on the characteristics of the 2009 BP. This period corresponds to the construction phase, during which massive construction teams are needed as well as significant numbers of design phase professionals (for quality control assurances, and other design engineering managerial roles) and managerial personnel (e.g., construction managers, supervisors) who will preside over the general construction workforce. During this peak period, the project is complex and multifaceted, and much of this section discusses implications during this period.

This section provides the results of the bottom-up estimation of the workforce needed to build and maintain the HSR network over the life of the project (2009–2025). Figure 4, which examines the 2009–2020 (pre-operating) period, illustrates that the conventional estimation model implies a peak period in 2015 whereas the bottom-up estimation results imply a peak period that lasts four years, roughly from 2013 to 2016. Overall, both estimations are almost the same, which tends to validate our bottom-up estimation that was benchmarked using the APTA (top-down) measurement method.

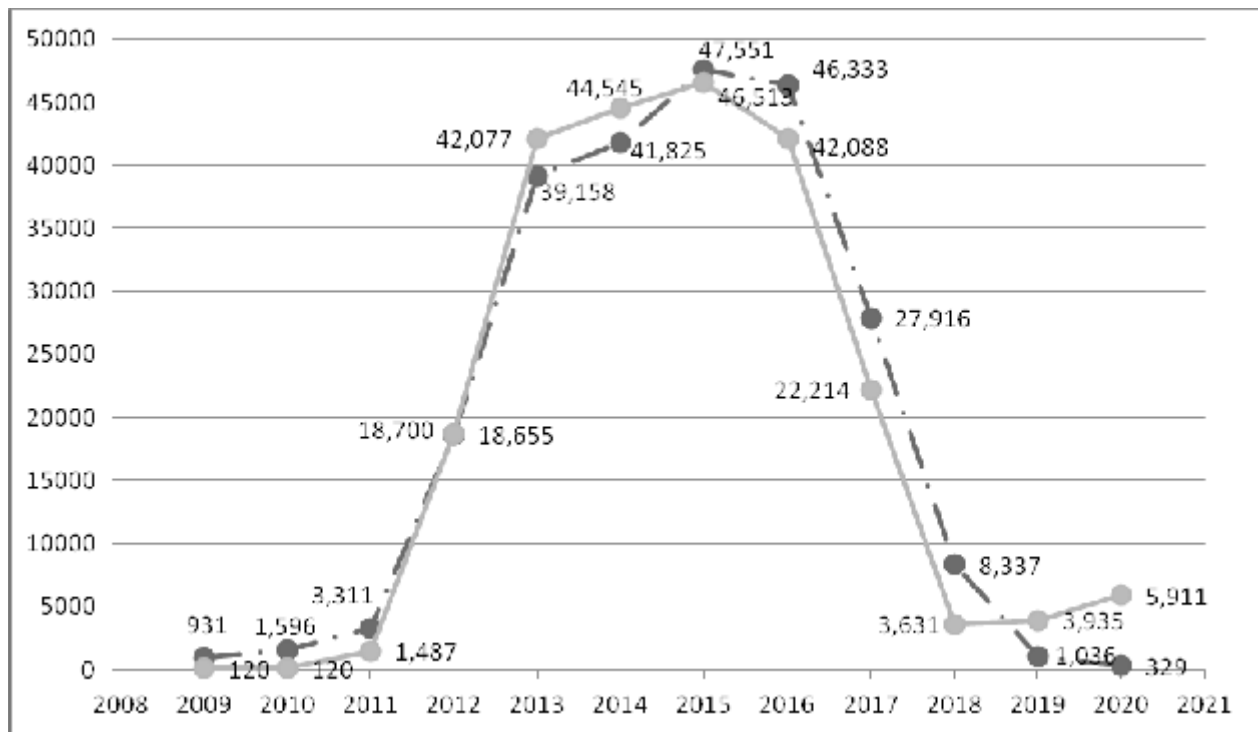


Figure 4. Mathematical Benchmark (dotted line) and Bottom-up Estimation (solid line), Personnel Wave 2009–2020

TOTAL EMPLOYMENT DEMAND BY TYPE OF POSITION

Employment, however, continues annually after the 2020 period, in the form of operations and maintenance personnel/professionals; as a result, we extend estimation of the impacts of the workforce to the 2025 period to measure the impacts of the operations and maintenance workforce. Figure 5 illustrates a comprehensive analysis of the workforce demand over the life of the project, including the operations phase, through 2025, which encompasses five years of maintenance professionals/personnel needs, based on the 2009 BP.

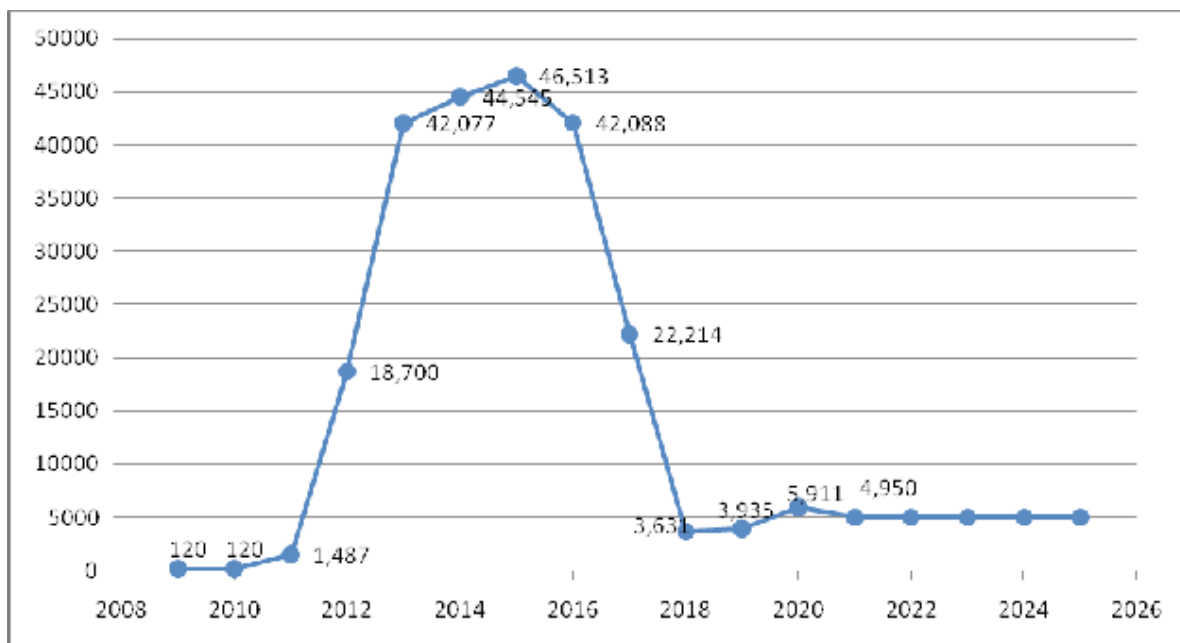


Figure 5. CHSR Personnel Wave, 2009–2025, Phase 1 of Project

Figure 5 contains a graphical representation of our comprehensive analysis of the workforce demand extended to 2025. Using these results, we can estimate total personnel (in PY) over the life of the project, including the operations and maintenance cycle. Next, we estimated the workforce over the life of the project by sector and occupation related to the DBOM of the system.

PY Phase (as a percentage)

We also disaggregate our total estimates into project phases (DBOM), as illustrated in figure 6, for the 2009–2025 period. Over the project delivery sequence, the design phase constitutes approximately 1 percent of the total workforce needed over the life of the project, build management 7 percent, build construction 79 percent, and operations and maintenance 13 percent (2019–2025 period, after the system has been constructed). There is a massive need for laborers during the build construction phase, which constitutes the major period of personnel need over the life of the project.

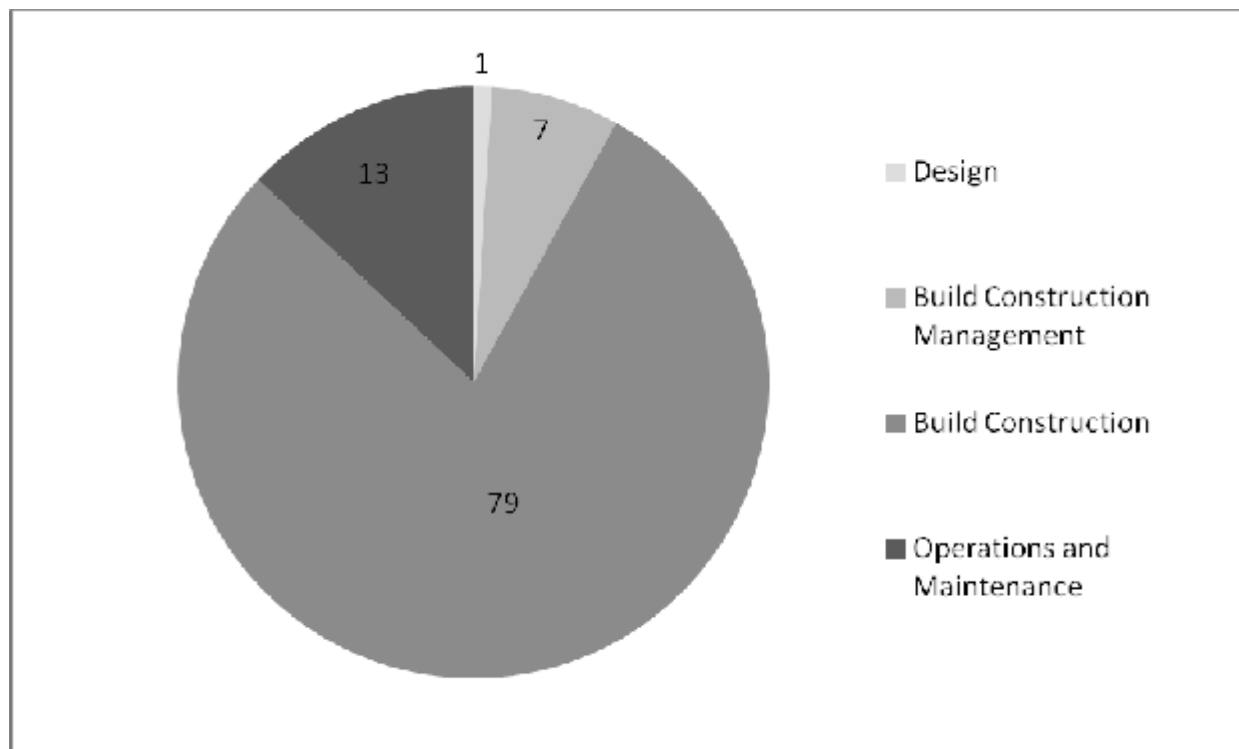


Figure 6. PY by Phase (As a Percentage of Total Workforce)

Next, we begin to look further into specific professionals/personnel demanded over the life of the project. Table 3 lists these professionals/personnel estimates, which comprise 90 percent of the estimated 256,092 direct PY for the life of the entire project (2009–2025). The table includes the total number of professions needed in PY, by rank, in the highest phase demanded (i.e., when primarily needed), and the total estimated PY for the top-25 positions. In this process, we identify the 25 most frequently required positions. As highlighted in dark grey, some of these positions are estimated over the 2019–2025 period for operations and maintenance phase professionals/personnel. Here, 13 percent of the workforce estimate in figure 6 pertain to the operations and maintenance phase estimate.

Table 3. Top-25 Professionals/Personnel Positions, Sequence of Demanded, and PY

Rank	Professionals/Personnel	Sequence Demanded	Total in PY
1	Construction Laborers	Build	68,897
2	Operating Engineers and Other Construction Equipment Operators	Build	55,015
3	Construction Carpenters	Build	16,269
4	Cement Masons and Concrete Finishers	Build	10,253
5	Rail Car Repairers	Operations and Maintenance	9,354
6	First-Line Supervisors/Managers of Construction Trades and Extraction Workers	Design and Build Management	7,934
7	Structural Iron and Steel Workers	Build	7,015
8	Cleaners of Vehicles and Equipment	Operations and Maintenance	5,642
9	Railroad Conductors and Yardmasters	Operations and Maintenance	5,278
10	Continuous Mining Machine Operators	Build	4,878
11	Crane and Tower Operators	Build	4,545
12	Engineering Managers	Design and Build Management	4,447
13	Electricians	Build	3,686
14	Construction Managers	Design and Build Management	3,489
15	Reinforcing Iron and Rebar Workers	Build	2,698
16	Rail-Track Laying and Maintenance Equipment Operators	Build	2,427
17	Rotary Drill Operators, Oil and Gas	Build	2,406
18	Service Station Attendants	Operations and Maintenance	2,327
19	Pile-Driver Operators	Build	2,290
20	Welders, Cutters, and Welder Fitters	Build	2,253
21	Pump Operators, Except Wellhead Pumps	Build	2,187
22	Excavating and Loading Machine and Dragline Operators	Build	2,009
23	First-Line Supervisors/Managers of Landscaping, Lawn Service, and Groundskeepers	Design and Build Management	1,985
24	Locomotive Engineers	Operations and Maintenance	1,970
25	Civil Engineers	Design and Build Management	1,828

Note that the vast majority of these positions are trade-oriented, including construction laborers, operating engineers and other equipment operators, cement masons and concrete finishers, structural iron and steel workers, and so on. In addition, there is a smaller, but significant, presence of managerial positions related to that construction. Historically, the construction management teams (i.e., business managers, general managers, construction managers, and first-line supervisors) represent a smaller percentage of the total workforce

needs, ranging from 10 to 18 percent of the total workforce.⁴⁹ Finally, a much smaller number of highly skilled civil engineers also are associated with the project, enough to rank within the top-25 professions needed over the life of the project.

Personnel Demand, During Build Construction Phase (Adjusted to 2009–2020)

A different profile emerges when we focus exclusively on the design, construction management, and build phase and exclude the operations and maintenance phase because the operations and maintenance phase (which would not begin until circa 2019) is replicated annually and would impact percentages during the latter years of the model, and so on. Table 4 recreates the estimates of the top-25 positions from table 3, exclusive of the operations and maintenance PY. When adjusted in this way, the design, build management, and build construction phase constitutes 98 percent of the total labor on the project (as there is still a single year in 2020 of full operations and maintenance employment). In contrast to the data presented in table 3, the build phase personnel contain a significantly higher number of general managers, forepersons, engineering managers, and construction managers, reflecting the importance of the managerial sector to oversee general labor practices in the project throughout the life of the build.

Table 4. Top-25 Professionals/Personnel Positions, Sequence of Demanded, and PY, Adjusted

Rank	Professionals/Personnel	Sequence Demanded	Total in PY
1	Construction Laborers	Build	68,897
2	Operating Engineers and Other Construction Equipment Operators	Build	55,014
3	Construction Carpenters	Build	16,269
4	Cement Masons and Concrete Finishers	Build	10,253
5	First-Line Supervisors/Managers of Construction Trades and Extraction Workers	Design and Build Management	7,934
6	Structural Iron and Steel Workers	Build	7,015
7	Continuous Mining Machine Operators	Build	4,878
8	Crane and Tower Operators	Build	4,545
9	Engineering Managers	Design and Build Management	4,446
10	Electricians	Build	3,686
11	Construction Managers	Design and Build Management	3,489
12	Reinforcing Iron and Rebar Workers	Build	2,698
13	Rotary Drill Operators, Oil and Gas	Build	2,406
14	Pile-Driver Operators	Build	2,290
15	Welders, Cutters, and Welder Fitters	Build	2,253
16	Pump Operators, Except Wellhead Pumpers	Build	2,187
17	Excavating and Loading Machine and Dragline Operators	Build	2,009
18	First-Line Supervisors/Managers of Landscaping, Lawn Service, and Groundskeepers	Design and Build Management	1,985
19	Civil Engineers	Design and Build Management	1,828
20	Paving, Surfacing, and Tamping Equipment Operators	Build	1,565
21	First-Line Supervisors/Managers of Mechanics, Installers, and Repairers	Design and Build Management	1,356
22	Rail-Track Laying and Maintenance Equipment Operators	Build	1,257
23	Plumbers	Build	1,105
24	Mechanical Engineers	Design and Build Management	1,030
25	Helpers: Pipe Layers, Plumbers, Pipefitters, and Steamfitters	Build	916

As highlighted in table 4, the estimation demonstrates the shared responsibility in the deliverables of the CHSR network build-out. The presence of management, both from the engineering side and complementary construction labor side, emerges. Managerial positions occupy 5 of the top-25 positions noted earlier, account for 9 percent of the PY positions, and 7.7 percent of total workforce composition. In discussing the construction sector, the top-two rankings account for a total percentage of 59 percent of the PY in the top-25 and 49 percent of the total estimated PY required for total system construction. With respect to the construction phase, needs associated with construction labor, operating

engineers and other construction equipment operators, and construction carpentry are preeminent. This workforce will be managed by a group of first-line supervisors/managers with various designations as well as engineering managers and construction managers, which will constitute a smaller percentage of the workforce.

Summary

Workforce characteristics shift over the phases of delivery, with different types of professionals and personnel required over the various phases. Key positions in design, build management, and build construction phases emerge, with management teams representing a smaller, but directive, role in the delivery of the project. Large numbers of laborers are identified with construction labor and operating engineers and other construction equipment operators dominating the ranks. Next, we link the PY that we have identified with the education backgrounds associated with each type of position, by phase, over the life of the project.

EDUCATION OUTCOMES SUMMARY

Each of the project phases implies a significantly different mixture of demand for education and training. For example, the design phase, focused on engineering, requires more employees with engineering degrees whereas the build construction phase requires relatively fewer employees with higher levels of education, but requires the greatest proportion of training for construction-related personnel. Implied in both cases is the need to train and educate this workforce to address emergent HSR system demands in technology and specialized skills. Next, we identify the types of training and education required for the positions associated with the project, by project phase. We also will identify the education requirements associated with the estimated peak period, which has the highest demand for personnel, and observe the patterns associated with that workforce at that time. Through this process, we will gain insight into the workforce and its likely needs for education created over the life of the CHSR project, creating a thorough description and inventory of the demand for education created by the construction of the HSR network.

We begin this process by examining the total need for education associated with the workforce over the life of the project through identifying the probability of each worker's education background. Connecting the total PY estimates to the likely occupational probabilities, table 5 exhibits the estimated demand, by level of education, over the life of the CHSR network construction.

Table 5. Level of Education Expected to be Attained by the CHSR Workforce, by Year, 2009–2025

Year	Less Than High School	High School	A.A./A.S.	Some College, No Degree	B.A./B.S.	M.A./M.S.	PhD	Total
2009	0	1	0	1	72	38	7	120
2010	0	1	0	1	72	38	7	120
2011	150	333	78	213	496	192	24	1,487
2012	4,973	8,147	594	2,428	2,199	317	43	18,700
2013	11,500	18,857	1,286	5,510	4,387	473	64	42,077
2014	11,960	19,681	1,392	5,853	5,067	526	67	44,545
2015	12,402	20,483	1,450	6,813	4,762	535	68	46,513
2016	11,378	18,683	1,353	5,586	4,482	538	68	42,088
2017	5,805	9,494	770	2,961	2,711	420	53	22,214
2018	662	1,182	174	559	764	257	34	3,631
2019	261	652	242	510	1,490	695	86	3,935
2020	407	2,034	552	1,446	1,039	368	65	5,911
2021	623	2,091	438	1,197	464	125	14	4,600–4,950
2022	623	2,091	438	1,197	464	125	14	4,600–4,950
2023	623	2,091	438	1,197	464	125	14	4,600–4,950
2024	623	2,091	438	1,197	464	125	14	4,600–4,950
2025	623	2,091	438	1,197	464	125	14	4,600–4,950
Annual Total Demand	62,613	110,003	10,081	37,866	29,861	5,022	656	256,092

Table 5 provides an estimate of the total direct workforce needed to complete the project, including the education required by the personnel we have identified. This table provides an initial linkage between the direct employment associated with the project and the education likely needed. These requirements are expressed in broad education groupings (e.g., level of degree attained); however, every employee, regardless of background and education, will require HSR-specific training and/or education. For example, many laborers will not require more than a high-school diploma, but those workers will require apprenticeships or other types of HSR-specific training experiences.

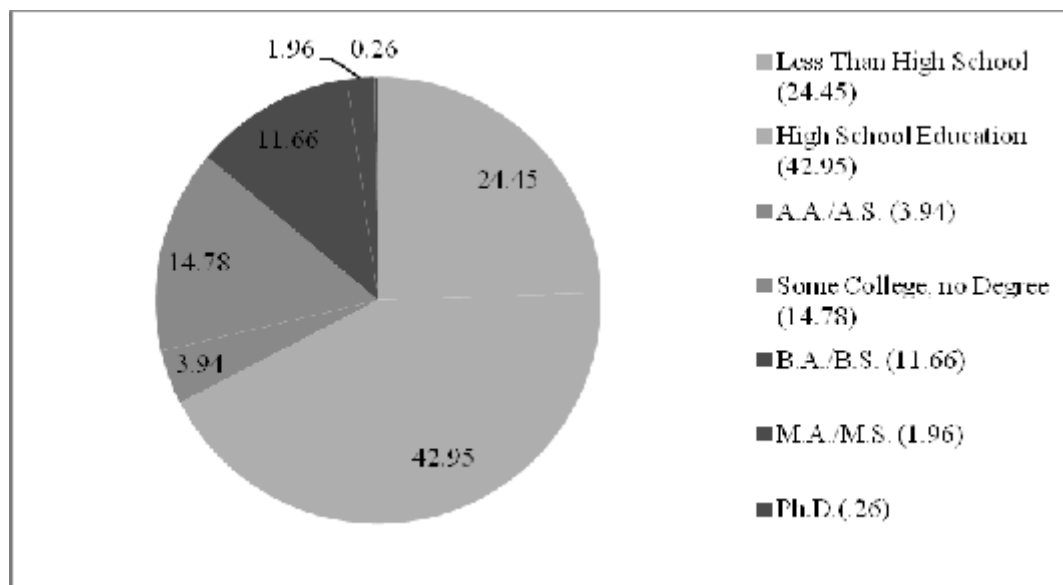


Figure 7. Education Needs (As a Percentage), CHSR Network Build-Out

Figure 7 provides an illustration of the percentages listed in table 5. The patterns that emerge are:

- Trades/construction employees (in light grey) at the high-school and below level constitute 67.4 percent of the total workforce. At this level of education, there is more need for employees who have a diploma than for those who do not (24.45 percent no diploma; 42.95 percent high-school diploma).
- The need for higher education is associated with 12.9 percent of the total workforce. Primarily, these will be B.A./B.S. holders.
- Some college training or education (no degree), including certification, constitutes 18.73 percent of the total workforce.

Workers with at least some college education constitute 30 to 32 percent of the total workforce, with less educated workers (high-school diploma and below) constituting 68 to 70 percent of the total workforce. Of those positions requiring higher education, some college (no degree) is the largest pool (e.g., certification process or other education), with BA/BS holders constituting the second-largest need for education. MA and PhD holders constitute around 2 percent of total workforce. Thus, approximately 70 percent of the workforce will require what is generally accepted as training through trades and similar programs, and approximately 30 percent will require training through institutions of higher education (community colleges and beyond). Some workers may avail themselves of both training and higher education experiences; our model cannot identify how many.

Interpretation

Figure 7 identifies three levels of need. The first level of need will be to train and educate massive numbers of workers in HSR construction training, which is a core competency of the trades partners. Applying a general metric, this implies training to target those with a lesser level of education, as depicted in figure 7 (although it is recognized that all workers

have some probability of holding more or less education than measured). The second level of need is classified as some college to A.A./A.S.-level holders, in which community colleges will be needed to train this diverse workforce over the life of the project. In the third level of need, there remains a small, but critical, B.A./B.S. and above workforce, who will be challenged with upper management and design responsibility as well as the education of some operations and maintenance personnel.

As discussed earlier, these estimates are based on probabilities and the assumption that certain patterns of education in similar workforces constitute the need for a degree in the HSR workforce. Ideally, there would be an explicit line drawn between our assemblage of education need and the specific training and education demands associated with each phase of the project. However, our data set is not sensitive enough to provide this level of detail. For example, just having a high-school degree does not connote readiness to work as an HSR construction worker, just as holding a BS degree in engineering does not necessarily imply readiness to work as an HSR engineer. Thus, more details regarding the specific types of training and education curricula are needed to create a comprehensive understanding of the workforce attributes of the future HSR system. However, these estimates do actively begin to frame education and training needs, with the understanding that each worker will need to be trained at a certain level to complete their HSR-specific jobs. Thus, although we cannot identify varied training and education needs down to specific curricula, we explicitly identify the total patterns of need, according to the total estimated workforce.

Table 6 helps to illustrate this generalization of anticipated needs across phases. We identify the need for B.A./B.S. and M.A./M.S. degrees as generally being a “prerequisite” to working as a member of the design phase team. Second, a wider range of levels of education anticipated during the build management and build construction phases exists. Simultaneously, demand for high education decreases, replaced by training needs for the construction workforce. Last, we see even more varied levels of need across the operations and maintenance phase.

Table 6. Total Direct Job (PY) Education Need Demographic By Phase, CHSR Network, 2009–2025

Phase	Design	Build Management	Build Construction	Operations and Maintenance
Less Than High School	0%	9%	28%	13%
High School	1%	21%	46%	42%
AA/AS	1%	6%	3%	9%
Some College, No Degree	2%	15%	13%	24%
BA/BS	61%	34%	9%	9%
MA/MS	30%	13%	0%	3%
PhD	5%	2%	0%	0%
Total PY	2,214	18,954	202,741	32,184

EDUCATION IMPACTS BY PHASE

Because each phase is characterized by markedly different employment needs, we provide the specific characteristics of each phase as well as additional analysis of the workforce during each phase, focusing on their education and training needs. Following the DBOM sequence, we will break the workforce into smaller increments, by phase, for analysis. For each phase, we will (a) identify the estimated total education needs for the phase, (b) explore the personnel demanded in the phase, and (c) identify the demand for education that is created by that phase among specific job types. We begin with the design phase.

Education Needs by Degree, Design Phase

The design phase is dominated by demand for engineering education. This is the preconstruction phase that is primarily conducted away from the site and is focused on the need to design systems that are modeled from existing engineering systems (through proven technology design) or designed by engineering teams, detail and engineering-oriented, and designed to be replicated across the CHSR system.

As a result, this phase will reflect a more educated and specialized workforce. The need for workers with bachelor's, master's, and doctorate degrees emerges during the initial phases of the design process, and the most commonly required bachelor's degree is in the field of civil engineering. Many experienced engineers obtain graduate degrees in engineering or business administration to learn new technology and broaden their education.⁵⁰ The MS and PhD levels also are statistical extensions of that civil engineering demographic (where half of the civil engineers hold an M.S. degree, and 10 percent hold a PhD). The PhD holders also are associated with positions related to both civil engineering and managerial engineering. Those not holding professional degrees are involved in processes such as designing and drafting, where an AA/AS degree or other level of education is

accepted, including specialization in that particular element (i.e., blueprinting, AutoCAD drafting, etc.). Those positions in our model include:

- Mechanical Drafters
- Electronics Engineering Technicians
- Transportation Vehicle, Equipment and Systems Inspectors, Except Aviation

Specifically, there are drafting roles, advisory roles, and other specialization that require lesser levels of education, as listed in table 7, which are primarily construction-experienced personnel who will provide insight into the design process. This is done to assure that engineering design meets construction capability. Overall, however, the design process is a deliverable that is engineering-dominated, and the spread of education composition of the design workforce reflects this directly in our education index. Table 7 contains the education needs of the design element for the top-ten positions of the design phase. The grey area in the table depicts the higher need for education during the design phase.

Table 7. Top-Ten Types of Positions During Design Phase

State of California Positions	Less Than High School	High School or Equivalent	A.A./ A.S.	Some College, No Degree	B.A./ B.S.	M.A./ M.S.	PhD
Civil Engineers	0	0	0	0	648	270	49
Engineering Managers	0	0	0	0	291	200	28
Mechanical Engineers	0	0	0	0	109	41	5
Electrical Engineers	0	0	0	0	93	42	9
Construction Managers	0	0	0	0	39	8	1
Management Analysts	0	0	0	0	26	18	4
Technical Writers	0	0	0	7	23	9	0
Regulatory Affairs Managers	0	0	0	0	23	11	2
Aerospace Engineers	0	0	0	0	21	12	3
Industrial Engineering	0	0	0	0	17	6	1

Predictably, table 7 illustrates the need for extensive engineering managerial teams for the design phase. This translates into the need for civil engineers, engineering managers, mechanical engineers, and electrical engineers. The managerial teams also are a main component of the design team. Notably, we have included aerospace engineers as a required engineering group during this phase due to the needs associated with the design of the HSR rolling stock. The designing of rolling stock requires advanced knowledge of structural capabilities related to aluminum as well as advanced slip stream characteristics (which accounts for the aerospace engineering designation). Other positions related to financial analysis, environmental processes, and extensive geotechnical matters will continue to be central team members in the delivery of Environmental Impact Report/Environmental Impact Statement (EIR/EIS) compliance processes. Generally, the design team is a specialized group of professionals who require extensive higher levels of education in support of design phase deliverables.

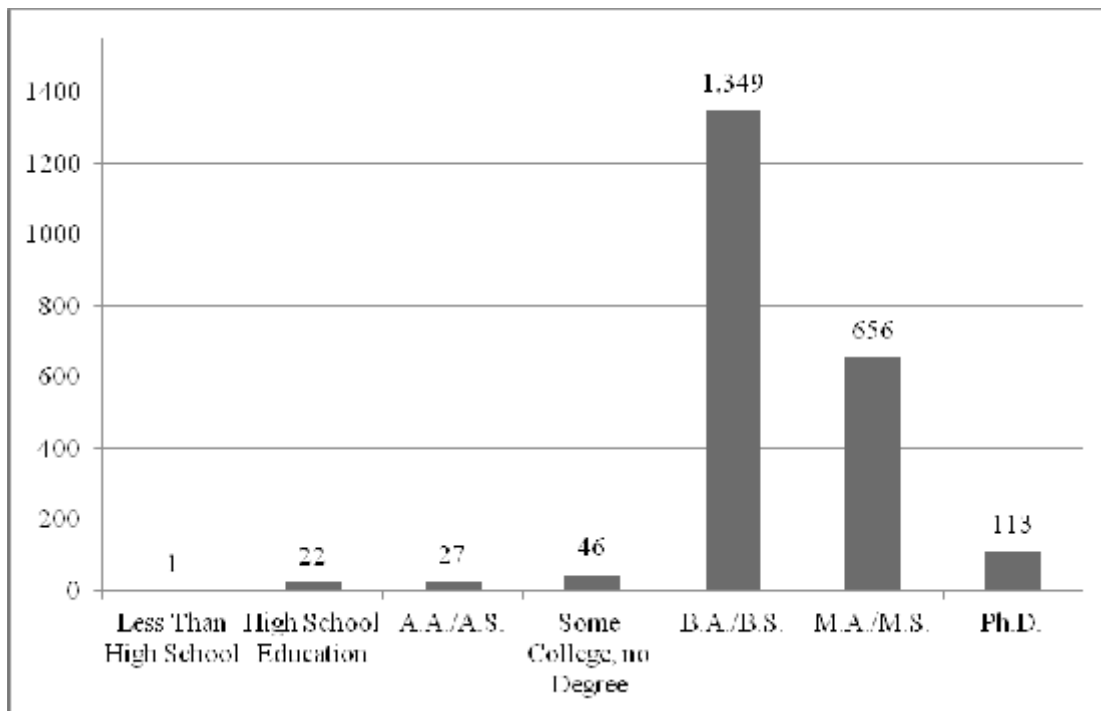


Figure 8. Education Needs by Degree, During Design Phase

The graph in figure 8 depicts the education characteristics related to the design team. These positions primarily entail college degrees and advanced degrees. The design team is comprised of engineers, so the demand during this phase also involves the need for engineering degrees, engineering management, and other specialized design degree holders.

During their roles in design, professionals prepare for the procurement process, completing all clearances to the EIR/EIS process, and extensively draft the documents needed to complete the CHSR network. During construction process, this team will function to create quality assurance and compliance. This is a comparatively small and elite team of engineering professionals who will be responsible for the project from the present to the 2020 period. After this period, a smaller division is projected to assure quality assurances and maintenance practice compliance, post-2020 period.

Education Needs by Degree, Construction Management Phase

Table 8 captures the workforce during the construction management phase. The construction process in our CHSR model is the transition point at which the project goes to ground. At this point, the Program Management Team shifts to a more advisory and managerial role (Specifically, once procurement bids are going to ground, there is a need to assure compliance with engineering design and specification). This is accomplished as construction management teams on the ground implement the designs rendered by the Program Management Team, and construction workers implement specific plans and tasks in accordance with the particular projects. Recognizing this, we accordingly identify a shift in the personnel and associated education traits. As table 8 implies, this period involves the quality control teams as well as other groups such as engineers and teams of experienced construction managers and supervisors.

For engineering demand, continued participation from the engineering teams (e.g., engineering managers, mechanical engineers, and civil engineers) is necessary. This workforce interacts directly with its counterparts by managing and directing construction through various key managerial positions (e.g., construction managers, and first-line supervisors/managers of various processes). We also observe the beginning participation of construction laborers, who will conduct basic setup and preparation processes. Supplementing the engineers, managers, and initial construction management workforce are the personnel affiliated with the preparation for field operations of the group including emergency management specialists, purchasing agents, and other administrators. Their likely needs for education are presented in table 8 and include an increased need for community college training (highlighted in lighter grey) as well as training of a high-school education level workforce.

Table 8. Build Management Phase Education Needs

Build Management Needs Sorted by BA, MA, and PhD Focus	Less Than High School	High School or Equivalent	A.A./A.S.	Some College, No Degree	B.A./B.S.	M.A./M.S.	PhD
Engineering Managers	0	0	0	0	2,196	1,528	216
Construction Managers	0	0	0	0	1,471	305	0
Mechanical Engineers	0	0	0	0	612	233	29
Civil Engineers	0	0	0	0	584	247	44
General and Operations Managers	0	0	0	0	303	112	22
Emergency Management Specialists	0	142	106	211	296	119	0
Purchasing Agents, Except Wholesale, Retail, and Farm Products	0	101	53	136	147	0	0
First-Line Supervisors/Managers of Transportation and Material-Moving Machine and Vehicle Operators	77	323	83	272	132	0	0
Construction Laborers	969	1,075	101	390	130	0	0
Civil Drafters	0	58	144	138	97	0	0
First-Line Supervisors/Managers of Mechanics, Installers, and Repairers	75	347	108	267	91	0	0
First-Line Supervisors/Managers of Construction Trades and Extraction Workers	140	387	60	222	80	0	0
Mechanical Engineering Technicians	0	112	108	157	67	0	0
Executive Secretaries and Administrative Assistants	12	148	59	155	63	0	0
Bookkeeping, Accounting, and Auditing Clerks	0	152	44	181	59	0	0
Emergency Medical Technicians and Paramedics	0	79	94	200	56	7	0
First-Line Supervisors/Managers of Production and Operating Workers	51	188	35	116	54	0	0
Rough Carpenters	236	419	50	183	0	0	0
Crane and Tower Operators	153	519	35	181	0	0	0

As indicated in table 8, during the build construction phase, the education demographic shifts toward the deployment of personnel with lesser levels of higher education as the construction process goes to ground. Holding constant the higher education needs for managers (i.e., the first five rows of table 8), the need for employees with community college degrees or some college increases. Such a pattern makes sense, as the design team and the field teams intersect, and now include construction management personnel (with skills in construction build practices), supplementing the previously deployed engineering

managers, civil engineers, and other design-affiliated professionals. With respect to new managerial positions as the project goes into the field, we particularly note the need for management:

- First-line supervisors/managers of construction trades and extraction workers
- First-line supervisors/managers of transportation and material-moving machine and vehicle operators
- Construction managers
- General and operations managers
- Emergency management specialists

Demands for Education Observed

During the build construction management phase, mechanical engineers with four-year degrees are now needed, there remains a need to train civil engineers, and there is an increased need for general and operations management, with training at the BA/BS level, and to a lesser extent at the MA/MS and PhD levels, respectively. In our model, engineering managers (as an extension of a BS degree) will always possess an advanced degree, construction laborers are estimated to possess a BA/BS degree just 3.8 percent of the time, and construction managers are estimated to always possess an advanced degree. Crane and tower operators and rough carpenters will not hold degrees but will require specialized training. Last, first-line supervisors/managers will on average possess a degree 9 percent of the time, will need community college training 37 percent of the time, and will only require a high-school diploma or equivalent 53 percent of the time. As a result, the varied levels of education, shown in figure 9 connote the need for varied levels of education during the build construction management phase. Thus, managerial positions tend to require college degrees during the construction management phase, in lieu of extensive on-site workforce experience.

The importance of the managerial role, and the level of education attained by these professionals/personnel, is recorded by the Bureau of Labor Statistics. Managerial personnel usually have a college degree or considerable experience in their specialty. Individuals who enter construction with college degrees usually start as management trainees or as assistants to construction managers. Those who receive degrees in construction science often start as field engineers, schedulers, or cost estimators. College graduates may advance to positions such as assistant manager, construction manager, general superintendent, cost estimator, construction building inspector, general manager or top executive, contractor, or consultant. Although a college education is not always required, administrative jobs usually are filled by those with degrees in business administration, finance, accounting, or similar fields.⁵¹ Generally, therefore, the construction management teams will hold a large share of degrees. Figure 9 summarizes in visual representation the spread of levels of education anticipated for the construction management phase.

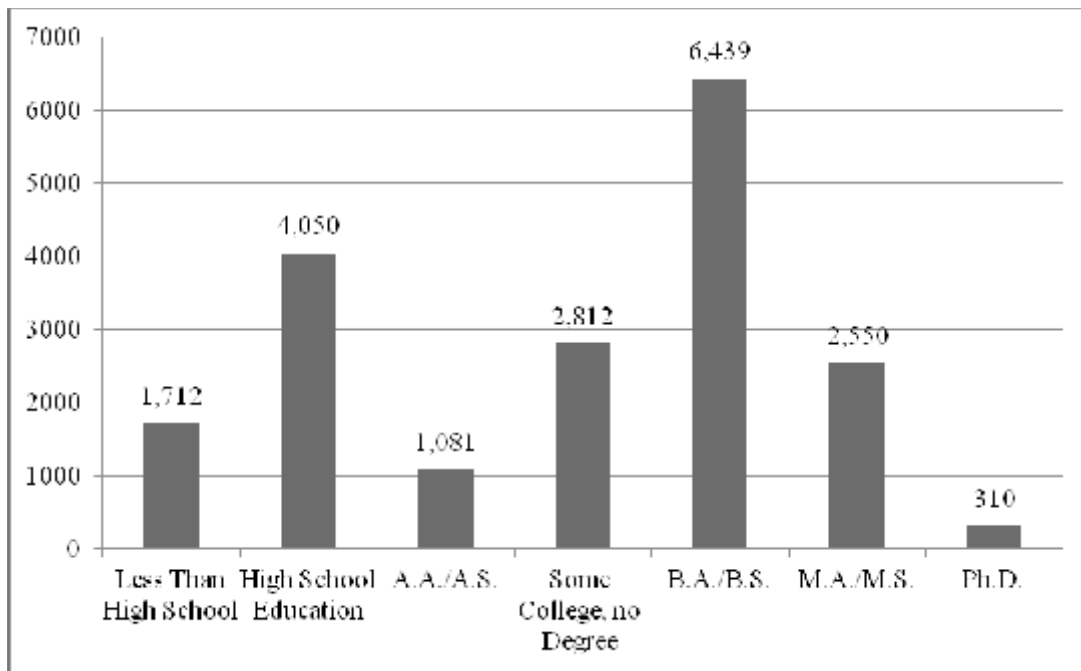


Figure 9. Construction Management During Build Phase, Degree Demand, 2012–2019, Expressed in Personnel-Years

To summarize our findings of the build management phase:

- This is the management group of the build phase. The construction management phase represents 18,954 PY of jobs (or 7 percent of the total estimated workforce, 2009–2025).
- Of the total construction management phase PY, 69 percent of the construction management workforce will require higher education, and 49 percent will require B.A/BS, MA/MS, or PhD degrees.
- Of the total construction management phase PY, 30 percent will require training at the trades/apprenticeship level.
- Construction managers are estimated to hold an advanced degree 58 percent of the time, and 47 percent of the emergency management specialists will hold a four-year degree or greater (BA/BS or MA/MS).
- The period is marked by the need for professionals who can communicate between the Program Management Team and the ground workforce preparing for construction of the network (as managers, supervisors, and lead-line persons) and who will be the critical linkage between the engineering teams and the workers on the ground.

Now that we have examined the construction management phase (which is a sub-phase of the construction phase that examines the managerial construction team), we now move to the critical build construction sub-phase, which constitutes 79 percent of the total workforce, estimated to be completed in the construction of the system in our model, over the life of the project.

Education Needs by Degree, Build Construction Phase

The construction function is much larger and more complicated than the construction management sub-phase; it is oriented around the delivery of many tasks and activities needed to physically deliver the project. It is massive and consists of a multitude of tasks involving many small and larger contracts. The smaller contracts will be required during the construction staging and prepping process; early work will include site clearing and grubbing, physical aspects of railroad track and facilities relocation, building demolition, environmental remediation work, and other utility relocations. The larger contracts will be awarded through the procurement of packages on specific project elements (i.e., station, aerial structure, maintenance facility, etc.) and will comprise the major labor elements of the project. The construction build period constitutes the major tasks and activities that are expected to occur in the build of the CHSR network.

The construction process is primarily staffed by the workforce designated to construct the network. Generally, it includes support management (through increased demand in managerial positions), massive amounts of personnel power (e.g., trades-driven work, laborers, cement masons, assemblers, welders, iron workers, etc.) and personnel with equipment-specific trades training (including drilling, bulldozing, and other extraction work) as well as support from architects and others holding advanced degrees.

The delivery of this work is equally as complex in terms of the anticipated workforce needs, given the scale of work, and the amount of work to be conducted in the 2012–2019 period. To address this complexity, we examine the build sequence data (over 202,000 variables), in three different ways. Specifically, we examine the (a) higher education needs, (b) labor-specific and worker-specific impacts, and (c) community college and certification impacts. We begin with higher education impacts.

University Education During the Build Construction Phase

Overall, there is limited, yet significant, need for workers with college degrees during the build construction phase. Table 9 depicts the workforce and education demand of the build period. Those generally needing higher education are primarily managers, architects, and supervisory positions. The need for education associated with the build construction phase will overlap between a university-educated workforce who hold managerial roles and potentially with elements of a highly skilled construction workforce, with general laborers sometimes holding advanced degrees (ranging from 8 to 20 percent⁵² of workers holding four-year degrees).

Table 9. Build Construction Phase Education Needs, by Job Type, Top-Ten

Education Needs Build Phase, Organized by Job Type	Less Than High School	High School	A.A./A.S.	Some College No Degree	B.A./B.S.	M.A./M.S.	PhD
Construction Laborers	23,490	25,701	2,370	9,212	5,089	0	0
Construction Carpenters	4,049	7,205	864	3,146	1,005	0	0
Construction Managers	0	0	0	779	917	190	0
First-Line Supervisors/Managers of Construction Trades and Extraction Workers	1,110	3,069	473	1,762	633	0	0
Architects, Except Landscape and Naval	0	0	0	0	324	176	54
First-Line Supervisors/Managers of Landscaping, Lawn Service, and Groundskeepers	393	673	166	450	303	0	0
Industrial Engineers	0	0	0	0	165	56	0
Pump Operators, Except Wellhead Pumpers	303	1,173	122	481	107	0	0

Table 9 provides an overview of the construction phase workforce. Construction managers, architects, and first-line supervisors/managers create the demand for higher education backgrounds during this time frame, with architects holding BA/BS, MA/MS, and PhD degrees, and construction managers holding both BA/BS and MA/MS degrees. Notably, the estimates for the education level of construction laborers suggest that they may be more likely to hold a higher level of degrees than might be expected.

Build Construction Phase Labor and Worker Training Needs

Table 10 contains a re-sorting of the construction phase labor force to focus on those employees who will not require any college education (i.e., most laborers). As demonstrated in table 10, the five most common positions constitute labor roles and training; the sixth position is taken by a managerial role. The workforce will require training that has presumably occurred within the trades industry, through apprenticeships or other training organizations.

Table 10. Trades/Apprenticeships Build Construction Phase Labor and Worker Education Needs, Top-Ten

Position	Less Than High School	High School	A.A./ A.S.	Some College, No Degree	B.A./ B.S.	M.A./ M.S.	PhD
Operating Engineers and Other Construction Equipment Operators	14,751	30,216	177	9,871	0	0	0
Construction Laborers	23,490	25,071	2,370	9,212	5,089	0	0
Construction Carpenters	4,049	7,205	864	3,146	1,005	0	0
Cement Masons and Concrete Finishers	4,390	4,408	217	1,238	0	0	0
Structural Iron and Steel Workers	1,327	3,604	449	1,635	0	0	0
First-Line Supervisors/Managers of Construction Trades and Extraction Workers	1,110	3,069	473	1,762	633	0	0
Continuous Mining Machine Operators	901	2,874	0	1,103	0	0	0
Crane and Tower Operators	631	2,136	144	746	0	0	0
Electricians	359	1,600	514	1,213	0	0	0
Reinforcing Iron and Rebar Workers	889	1,363	0	446	0	0	0

The positions in table 10 account for 95 percent of the total estimated construction build phase workforce requiring no more than a high-school education. When reordered in this manner, trades training needs are demonstrated for many groups of laborers identified with the build construction process. Thus, trades training will play a significant role in preparing these workers to be part of the CHSR network build.

The final examination reorders the data to focus on those employees with community college education needs, shown in table 11 as the “A.A./A.S.” and “Some College, No Degree” columns, during the build process.

Table 11. Build Construction Phase: Community College Education Needs, Top-Ten

Position	Less Than High School	High-School Education	A.A./A.S.	Some College, No Degree	B.A./B.S.	M.A./M.S.	PhD
Construction Laborers	23,490	25,071	2,370	9,212	5,089	0	0
Construction Carpenters	4,049	7,205	864	3,146	1,005	0	0
Electricians	359	1,600	514	1,213	0	0	0
First-Line Supervisors/ Managers of Construction Trades and Extraction Workers	1,110	3,069	473	1,762	633	0	0
Structural Iron and Steel Workers	1,327	3,604	449	1,635	0	0	0
Cement Masons and Concrete Finishers	4,390	4,408	217	1,238	0	0	0
Operating Engineers and Other Construction Equipment Operators	14,751	30,216	177	9,871	0	0	0
First-Line Supervisors/ Managers of Landscaping, Lawn Service, and Groundskeepers	393	673	166	450	303	0	0
Crane and Tower Operators	631	2,136	144	746	0	0	0
Pump Operators, Except Wellhead Pumpers	303	1,173	122	481	107	0	0

Table 11 contains reordered construction phase data that focus on workers who will have community college educations. A large number of the trades employees are estimated to hold A.A./A.S. degrees or other accreditation beyond the high-school diploma. Thus, the community college system will likely play a critical role in supporting the teams building the CHSR network, including construction laborers, construction carpenters, and electricians training that have obtained certification at the community college level in various programs. The top-seven positions listed in table 11 provide evidence of significant demand for some level of accreditation, including a relatively higher proportion of workers with A.A./A.S. degrees. Other forms of limited college education may be in the form of certification, including such positions (listed and unlisted in table 11) as crane and tower operators, pump operators, wellhead pumpers, welders, cutters, and welder fitters, oil and gas, reinforcing iron and rebar workers, pile-driver operators, and plumbers.

Summary of Build Construction Education Composition

Figure 10 contains a summary of the total education demand that is created during the build phase; massive demand will exist for those who hold only high-school educations, but are likely to require additional training. Roughly 150,000 PY with high-school diplomas (68 percent of the phase workforce) will be required. Community college/accreditation will likely be required of 33,000 PY of this workforce (16 percent of the phase workforce).

Those with B.A./B.S. and higher degrees will constitute 9 percent of the total estimated phase workforce, with 18,000+ PY affiliated with this group. However, despite the significant need for college-educated workers, the construction build process will be primarily driven by those who have acquired training outside of higher education systems.

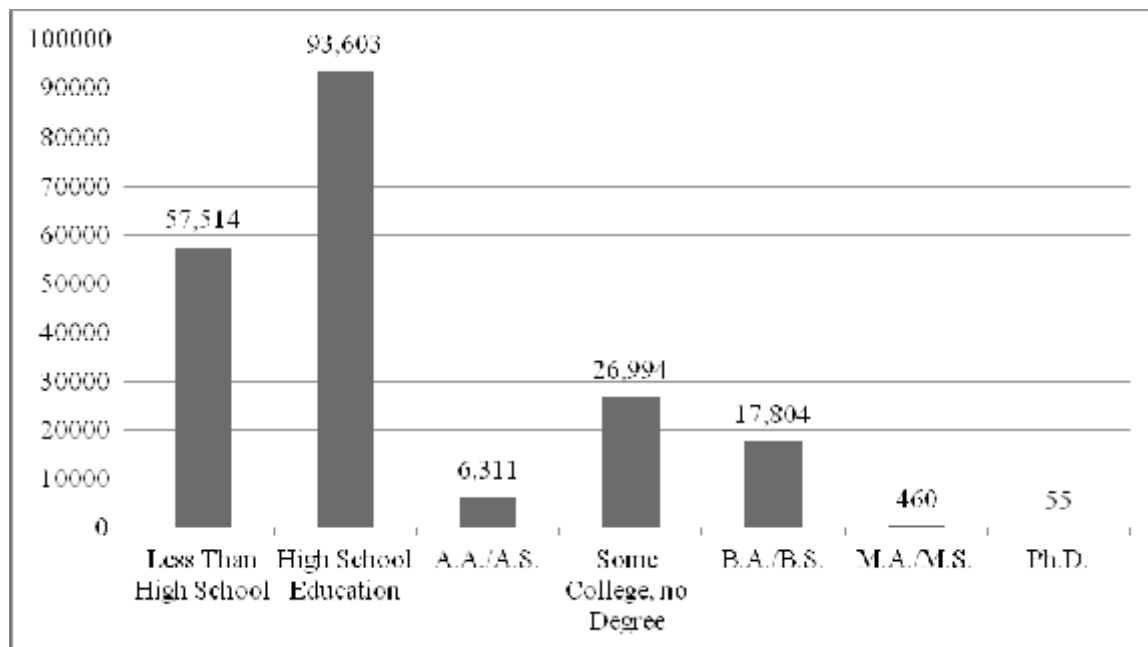


Figure 10. Construction Build Phase Degree Demand, PY, 2012–2019

In summary of the Build Construction phase:

- It is the main build period of the project; construction build activity represents an estimated 202,741 PY of jobs (or 79 percent of the total project workforce, 2009–2025).
- Although approximately 25 percent of this part of the workforce will require at least some higher education, only 9 percent will require four-year degrees (or higher).
- The bulk of the training/education is expected to take place in community college HSR managerial training programs or in trades/apprenticeship certification programs.
- Seventy-five percent of construction build personnel will be trained at the trades/apprenticeship level, including both certification to work on-site, HSR-specific trainings, and other specialized training.

Education Needs by Degree, During Operations and Maintenance Phase, 2020–2025

This section addresses the education needs of the operations and maintenance phase in the CHSR network, beginning in the 2019–2020 period. A key near-term activity for the project is contracting the system operator. The operations and maintenance contract could be structured in a variety of ways; it could be packaged with the core systems procurement or separately as a long-term (multi-year) concession. The exact timing and structure of this procurement has not been decided, although an initial Request for Expression of Interest for the system operations and maintenance contractor began in 2008. Recognizing that there are different ways to implement the operational and maintenance package, we have estimated the total personnel affiliated with the processing in accordance with the commentary by CHSRA.

Operations and Maintenance by Job Category

Operations and maintenance involves a multiplicity of positions that have different divisions of responsibility. There are four notable categories of personnel (Operations, Maintenance-of-Way, Maintenance of Equipment and Rolling Stock, and Administrative/Managerial), which are summarized in table 12 by level of education and job category. The data in table 12 correspond to estimation of a typical one-year period, which is scheduled to be extended for six and one half to seven years in our model.

Table 12. Operation and Maintenance Phase, by Division

Division	Less Than High School	High School	A.A./ A.S.	Some College, No Degree	B.A./ B.S.	M.A./ M.S.	PhD	Total
Operations and Maintenance	0	661	142	488	137	0	0	1,428
Maintenance-of-Way	66	228	76	181	70	16	3	640
Rolling Stock and Infrastructure Maintenance	502	1,015	171	422	0	0	0	2,111
Business Specialists	10	38	18	20	224	100	10	419
Total	579	1,942	407	1,111	431	116	13	4,598

To prepare total year estimates for the period, the measurements in table 12 can be multiplied roughly by seven (2019–2025), as a means to show total demand for degrees, over that time period. A high-school education is necessary for a plurality of workers (i.e., 53.8 percent will have attained this level of education), followed by some college, no degree (24 percent). An estimated 9 percent will hold community college AA/AS degrees. However, as we currently do not have the sufficient data to precisely identify the specific training or education needed for these groups, further exploration of this demographic is needed. In terms of levels of higher education, there is an estimated need for BA/BS holders, followed by MA/MS and PhD holders, respectively. Professionals with BA/BS, MA/MS, and PhD degrees total 12 percent of the estimated workforce.

The educational demographic for a model year for the operational and maintenance on the system is listed in table 13, based on an estimated annual need of 4,598 personnel.

Table 13. Operations and Maintenance Education Demographic, 1 Year Observed

Positions	Less Than High School	High School	A.A./A.S.	Some College, No Degree	B.A./B.S.	M.A./M.S.	PhD
Railroad Conductors and Yardmasters	0	296	86	275	97	0	0
Accountants	0	0	3	0	51	16	0
Computer Support Specialists	0	0	20	36	41	9	0
Financial Managers, Branch or Department	0	0	0	12	38	17	2
Management Analysts	0	0	4	0	35	25	6
Sales Managers	0	0	0	0	35	12	0
Service Station Attendants	0	205	22	79	26	0	0
Materials Engineers	0	0	5	5	19	7	3
Sales Engineers	0	0	0	0	17	6	0
Purchasing Managers	0	0	0	0	17	7	0
Budget Analysts	0	0	0	0	15	8	0
Transportation Managers	0	22	6	19	13	0	0
Financial Analysts	0	0	0	0	13	9	2
Telecommunications Equipment Installers and Repairers, Except Line Installers	0	0	11	21	7	0	0
Signal and Track Switch Repairers	7	18	4	12	4	0	0
Executive Secretaries and Administrative Assistants	1	8	3	8	3	0	0
General and Operations Managers	0	0	0	0	0	0	0
Rail-Track Laying and Maintenance Equipment Operators	29	120	15	53	0	0	0
Rail Car Repairers	206	667	141	322	0	0	0
Maintenance and Repair Workers, General	40	119	29	54	0	0	0
Locomotive Engineers	0	138	28	115	0	0	0
Cleaners of Vehicles and Equipment	296	349	30	100	0	0	0

Here, we discuss the education preparation associated with various operations and maintenance positions. Thirteen percent of the total personnel will require less than a high-school education. These positions are involved primarily with cleaning and maintenance activities. High-school-educated personnel are estimated to constitute 42 percent of the workforce for operations and maintenance, including some minor administrative roles,

attendants (station and onboard train services), and HSR locomotive engineer operators. Both those with A.A./A.S. degrees and with some college, no degree are statistical extensions of personnel with higher levels of education, or occupy accounting/financial specifications where an A.A./A.S. functions to train the individual in that role. The B.A./B.S. holders include general and operations managers, service station attendants, railroad conductors and yardmasters, computer support specialists, management analysts, sales managers, and sales engineers. Those with M.A./M.S. and PhD degrees tend to represent managerial and analysis roles for these administrative and business positions.

Total Demand for Education During the Operations and Maintenance Phase

When we focus on only the higher education attributes of the operations and maintenance workforce (with the data sorted by degree, as in table 13), major railroad conductors and yardmasters comprise a large proportion of those with college degrees; 13 percent of these employees are estimated to hold a B.A./B.S. degree. Accountants are forecast to hold a B.A./B.S. 95 percent of the time or more, and computer support specialists are estimated to hold advanced degrees 47 percent of the time. Among financial managers, branch or department, an estimated 83 percent will hold advanced degrees, and among management analysts, 93 percent will hold advanced degrees. All sales managers and marketers are estimated to hold advanced degrees. Training, especially in the managerial functions, will need to precede system operations that are projected to begin in 2019 onward. As a result, we see patterns showing that administrative and managerial workers of the operational and maintenance sequence will require higher education degrees.

Summary of Operations and Maintenance Phase

The greatest demand during this phase will be for high-school graduates (~30,000 PY over six and one half to seven years). Among those positions associated with community college backgrounds, the greatest demand will be in the areas of some college (no degree). B.A./B.S. degrees holders represent the predominant group who will have obtained higher education, including general and operations managers, service station attendants, railroad conductors and yardmasters, computer support specialists, management analysts, sales managers, and sales engineers. Rail car repairers emerge as the most needed personnel for the 2020–2025 period, with cleaners of vehicles and equipment personnel also in high demand. Railroad conductors and yardmasters represent the third-highest demand. Figure 11 exhibits the total need for degrees over the 2020–2025 period.

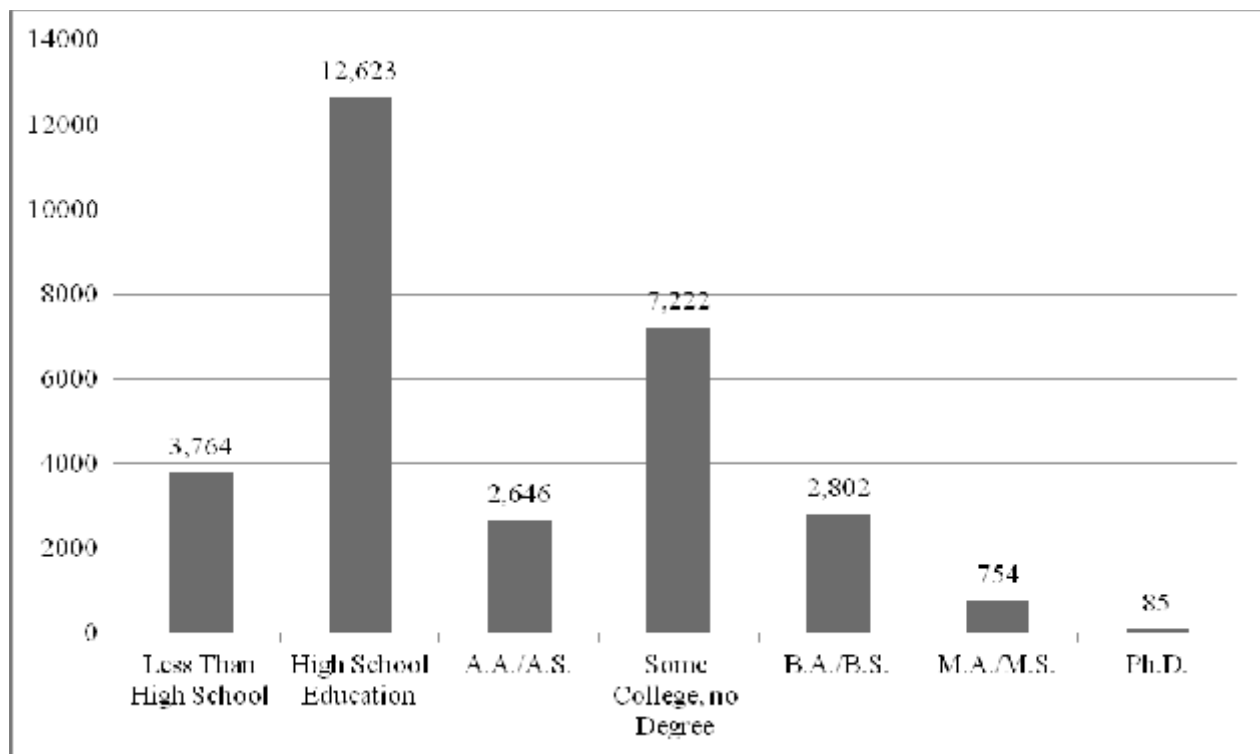


Figure 11. Operations and Maintenance Phase Degree Demand, 2020–2025 Observed (In Annual PY)

Key findings concerning the Operations and Maintenance phase, include:

- Operations and maintenance workers comprise an estimated between 4,500 to 4,950 PY annually (or 13 percent of the total estimated workforce for the project from 2009–2025).
- This is a diverse workforce with four levels or divisions: operations, Maintenance-of-Way, maintenance of rolling stock, and managerial roles.
- For this phase, 55 percent of the annual workforce will require trades/apprenticeship-based training and/or certification.
- Railroad conductors and yardmasters, rail car repairers, and cleaners of vehicles and equipment will be the three most frequently hired positions.
- Six administrative and managerial positions will constitute the most frequent need for college degrees, including accountants, management analysts, financial managers (branch or department), computer support specialists, sales managers, and some railroad conductors and yardmasters.

SUMMARY: EDUCATION NEEDS BY PROJECT PHASES, 2009–2025

Table 14 contains a useful summary of the education backgrounds estimated to be associated with the total HSR workforce in each phase of the project. The design phase is characterized by the need for many individuals with college degrees, including many advanced degrees. The build construction management phase marks the entry of many workers with either only high-school diplomas or some college (no degree). This trend is magnified during the build construction phase, when the plurality of workers is forecast to require only a high-school education or less. The operations and maintenance phase requires a diverse workforce with respect to training and education.

Table 14. Education Demographic by Phase, Recap

Phase	Less Than High School	High School	A.A./ A.S.	Some College, No Degree	B.A./ B.S.	M.A./ M.S.	PhD	Total
Design	1	22	27	46	1,349	656	113	2,214
Build Management	1,712	4,050	1,081	2,812	6,439	2,550	310	18,954
Build Construction	57,514	93,603	6,311	26,994	17,804	460	55	202,741
Operations and Maintenance	4,049	13,593	2,846	7,778	3,017	810	88	32,184
Total by Level of Education	63,276	111,268	10,265	37,630	28,609	4,476	566	256,090

WORKFORCE DEVELOPMENT NEEDS DURING PEAK PERIOD

The peak period is a point of estimation when demand for personnel and professionals is at its highest. This helps us to understand how many personnel will need to be trained in preparation for that most labor-intensive time. Peak period in our model is characterized by four years of intensive PY demand, as seen in figure 12. During this time frame, over 42,000 direct jobs are occurring simultaneously over a four-year period. Next, we explore need for education that is estimated to occur over this period. These estimates are based on Phase 1 project parameters, and any changes would be likely to our modeling, including the precise timing and intensity of the peak period. However, we find these figures are robust enough for both mid- and long-term planning.

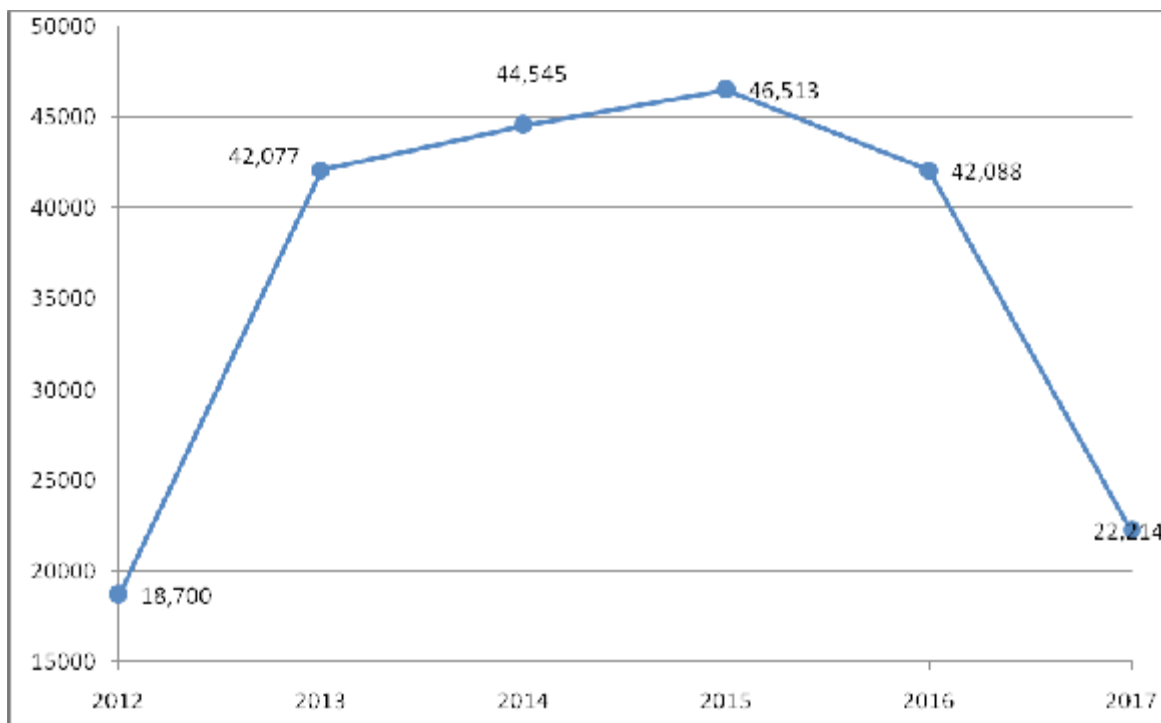


Figure 12. Peak Demand for Phase 1, 2013–2016, CHSR Project

Table 15. Peak Year(s), 2013–2016, CHSR Network Build-Out

Year	Less Than High School	High School	A.A./A.S.	Some College, No Degree	B.A./B.S.	M.A./M.S.	PhD	Total
2013	11,500	18,857	1,286	5,510	4,387	473	64	42,077
2014	11,960	19,681	1,392	5,853	5,067	526	67	44,545
2015	12,402	20,483	1,450	6,813	4,762	535	68	46,513
2016	11,378	18,683	1,353	5,586	4,482	538	68	42,088

In table 15, we highlight the requirements for various levels of education estimated to be required of employees during each of the four years, 2013–2016. As during the build construction phase as a whole, a majority of the workforce positions will not require college degrees, although many positions will require some college or an A.A./A.S. degree. Nevertheless, a significant number of positions will require four-year degrees or more. Figure 13 depicts the totals over the entire four-year period. As expected, the ratios of personnel need and need for education remain relatively constant; 71.3 percent of the workforce will be educated at the high-school level or equivalent, 17 percent will hold A.A./A.S. degrees or certification at the community college level education/training system, and 12 percent will hold B.A./B.S. degrees or higher.

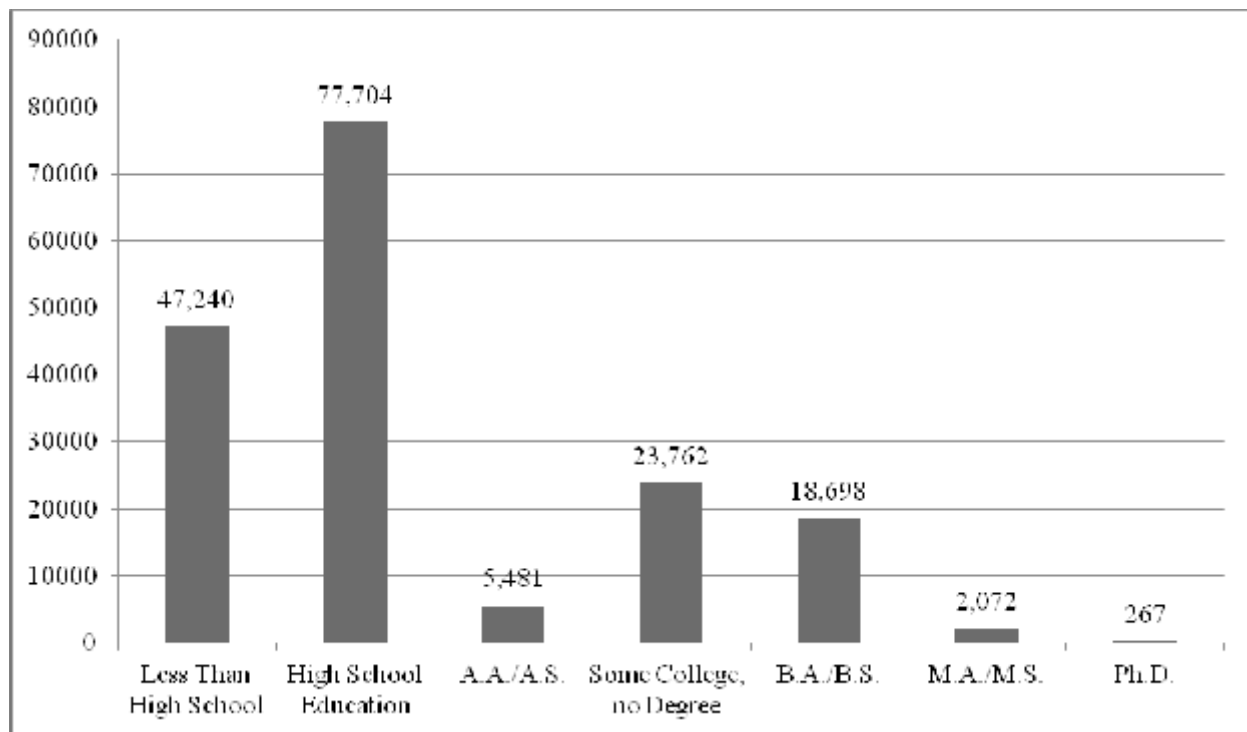


Figure 13. Peak Year(s), 2013–2016, CHSR Network Build-Out Education Demographic

PRELIMINARY ESTIMATES ACCORDING TO THE CHSRA 2012 BP

The bottom-up methodology employed in this project can be readily adopted to reflect changes between the 2009 BP and the 2012 BP recently released by the CHSRA. The 2012 BP reflects a series of changes that will warrant a notably larger pool of personnel/professionals, implying that education needs of the workforce may be even higher than those we have presented to this point. Such factors include:

- **Time:** The project under the 2012 BP is anticipated to last for a longer project delivery period (into the 2033 period), which connotes the need for more labor over a larger period.
- **Segmented Project Delivery:** According to 2012 BP, the CHSR project has been outlined as a multi-tiered project, a deviation from the 2009 projection. Each of these cost waves concomitantly represents up to five independent labor cycles, and calls for a pattern of increases and decreases in the demand for labor/professionals, over the life of the project.
- **Quantities:** The Central Valley Spine Construction is now more complex than as presented in the original 2009 BP. More aerial structures are anticipated to be needed in the Central Valley region, increasing labor needs. Our preliminary assessment of the newly planned aerial structures identifies a total need of between approximately 85,000 and 115,000 total PY to complete the tasks and activities in the Central Valley region.

- **Unit Prices:** Another major factor that may increase the need for labor in our model is the new cost estimation data (per element) that has been released, which contributed to the projected increased total costs for the project. Specifically, the new BP projects increased cost for elements, based on the new assessments of corridors. (Track, viaducts, tunnels, walls, buildings, utilities, mitigation, electrification, and right-of-way have increased in cost.)

These factors translate to greater need for labor over the life of the project. As depicted in figure 14, approximately 350,000 workers will be employed between 2012–2033 (excluding operations and maintenance personnel). After applying multiplier effects, over 1,100,000 PY will be needed in total. This projection includes the workforce needed for the 2012–2033 period, with an estimated 18 years of continuous workforce need of over 19,600 direct PY annually. In total, therefore, more than 1,100,000 total PY of employment are estimated to be created during the construction of the CHSR system, according to the requirements in the 2012 BP.

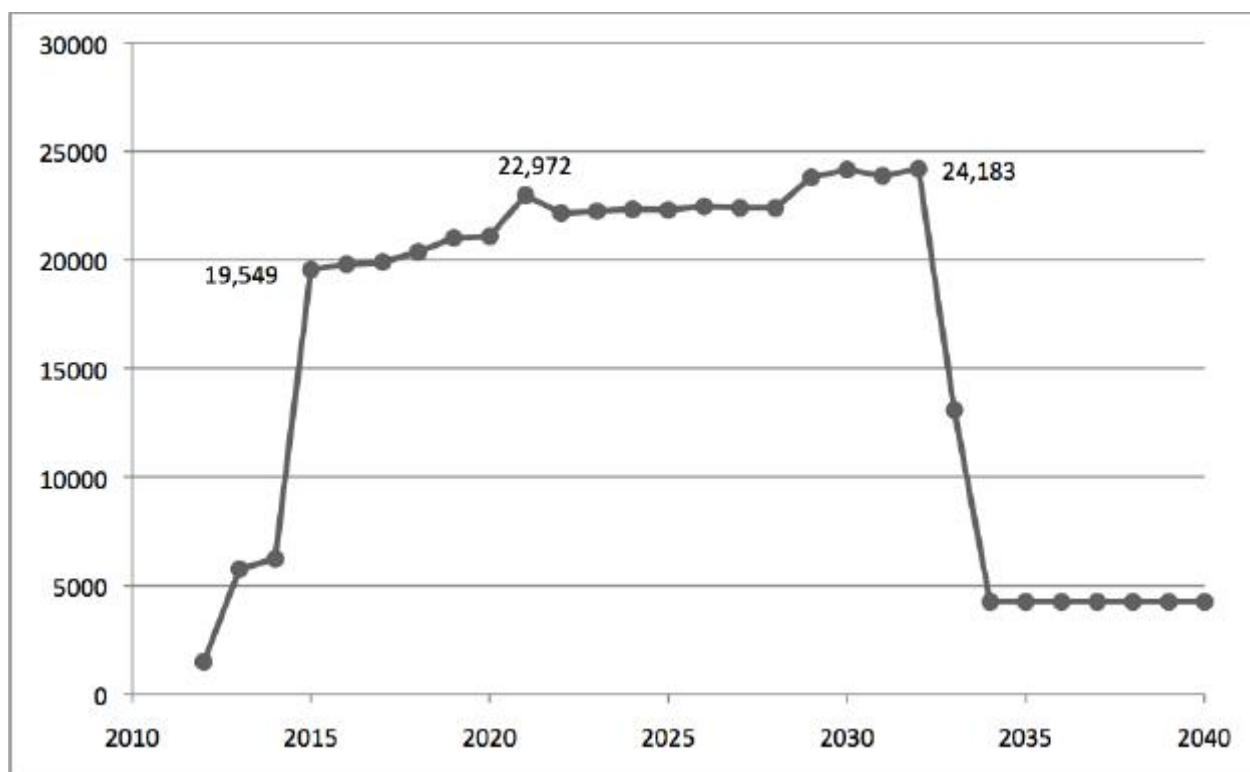


Figure 14. 2012 BP CHSR Workforce Demand, Direct Personnel in PY, 2012–2034

Figure 14 depicts the workforce demand for the CHSR network for the 2012–2040 period, demonstrating a different labor demand curve according to the 2012 BP. In Figure 14, there is an initial spike of need as early as 2015, a minimal spike in demand in the 2021 period, and the average workforce needed is estimated at approximately 21,000 personnel/professionals annually for an extended (2014–2033) period. Adding the need for operations and maintenance employees in 2032 onward creates an even higher direct workforce projection.

Implications for Education

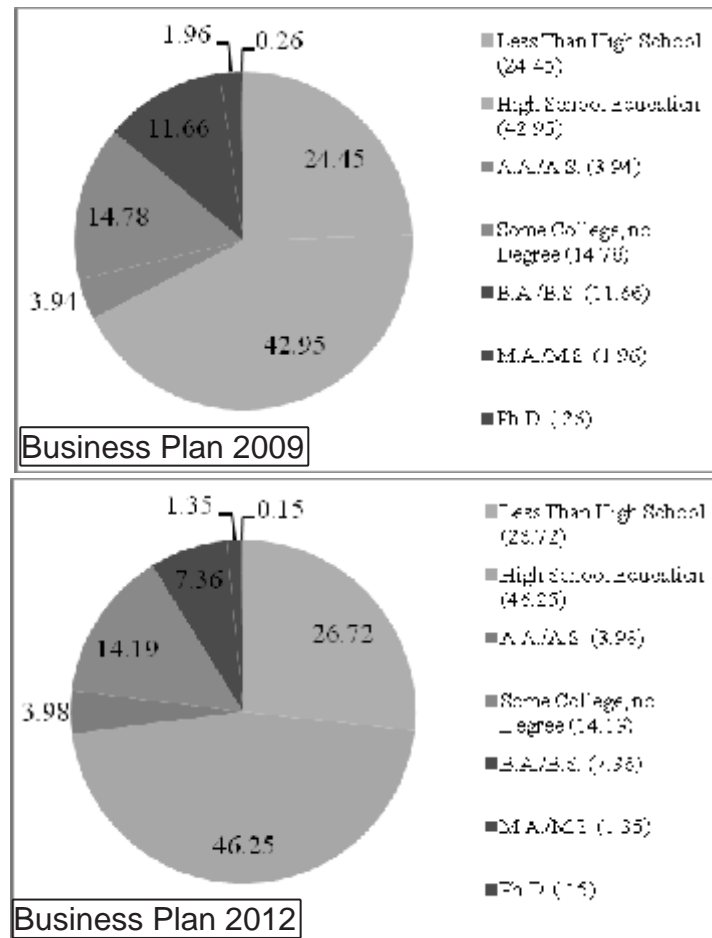


Figure 15. Education and Training Levels, CHSR Project, 2012–2033

More subtle changes in the education backgrounds estimated to be required by the HSR workforce are created by the changes in the 2012 BP. Figure 15 depicts the projected education needs, by percentage of the total HSR workforce, comparing the 2009 and 2012 BPs, and indicates negligible differences between the two projected workforces. Under both plans, construction workers with a trades education comprise the largest group, approximately 80 percent of the HSR workforce (including construction management), although significant numbers of college-educated workers will be required at this time, with the majority needing course work or certificates from community college level programs. Thousands more employees will require bachelor, master's, or doctoral degrees during the same period. In essence, the new (2012) BP appears to have little impact on the education demographics of the HSR workforce.

CONCLUSIONS

Total Direct Employment Demand Findings

Based on our combination of data sources and estimation methods outlined in this section, the total estimated number of direct jobs for the Phase 1 project delivery sequence is at 256,092 PY of direct jobs. This comprises the sum of direct laborers and professionals associated with the four major phases of project delivery: DBOM (from 2019–2025), based on independent estimates using the proposed CHSR model.

Table 16 depicts the total number of PY required, by phase of the project. The most labor-intensive phase of the project is build construction. By linking these positions to the education associated with each in existing data sources, we have shown that each phase of the project requires a different composition of workers, and thus a different level of education/training needs and support.

The design phase is categorized by the needs to educate and train engineering teams, including engineering managers, construction managers, mechanical engineers, civil engineers, and general and operations managers. During the shift to the construction management phase, demand for training education also includes support for key supervisory positions, such as emergency management specialists, first-line supervisors/managers, material-moving machine and vehicle operators, other various managerial and supervisory roles, as well as the augmentation of general staffing that will function as the management team in the field. During the shift to the construction build phase, which constitutes the bulk of the labor and personnel needs in the project, vast numbers of laborers, electricians, cement masons, and machine operators of many kinds will be needed. The final phase, operations and maintenance, is categorized by a smaller (4,020–4,950) and continuous need for personnel/professionals. Table 16 summarizes the percentages of personnel/professionals, by each phase.

Table 16. Total Personnel, by Phase (PY)

Phase	Total	% of Total
Design	2,214	1.0%
Build Management	18,954	7.4%
Build Construction	202,741	79.2%
Operations and Maintenance	32,184	12.5%
Total	256,090	100.0%

Need for Education and Training

We linked data concerning the likely training and education needs of the 256,000+ workforce. Figure 16 contains an overview of the education backgrounds that will be associated with these positions over the course of the entire project. Among the notable projections:

- The training need for trades/construction employees with high-school diplomas or less constitutes 67.4 percent of the total workforce; most—if not all—of these employees will require HSR-related training, however.
- Those with college degrees will constitute approximately 14 percent of the total workforce, primarily those with four-year degrees and a smaller percentage holding M.A./M.S. and PhD degrees.
- Another approximately 19 percent of the total workforce will possess A.A./A.S. degrees, or a some college (no degree) designation, presumably including short-to-medium term certification programs.

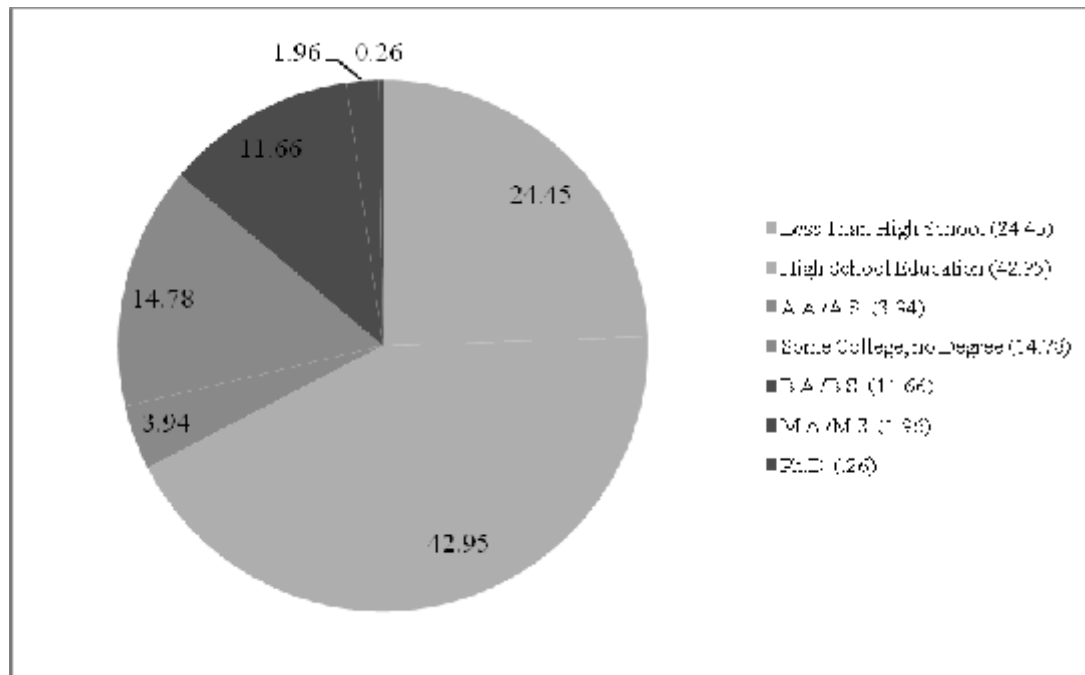


Figure 16. Education and Training Needs (As a Percentage), CHSR Network Build-Out

Education Needs by Phase

We have analyzed the personnel estimates of general education and training needs to identify patterns of need associated with each position in each phase. Table 17 demonstrates that the design phase is characterized by a need for (a) many workers with college degrees, including those with B.A./B.S. degrees (61 percent), M.A./M.S. degrees (30 percent), and some PhD degrees as well (9 percent); as well as (b) workers with some college (no degree), A.A./A.S. degrees, and high-school education or less also will be required. Likely education requirements for the build management phase are even

more varied, with the largest need for B.A./B.S. holders (34 percent), and the second-largest need for high-school-educated personnel (21 percent). During build construction, there will be a marked shift toward the need for less educated workers, including a majority of those with a high-school education (46 percent), or less (28 percent); however, 25 percent of the build construction phase workforce will likely need to hold college degrees. Operations and maintenance implies a wide range of education need, with 55 percent of the workforce requiring a high-school education or below, and the remainder with a variety of college backgrounds. Table 17 identifies the education needs and where the highest impact on education occurs (in bold) in each phase.

This measurement of education needs is only suggestive of how many professionals/personnel will require HSR-specific education and training and what forms that component of their education will comprise. That is, regardless of the level of education that is associated with each position during each phase, nearly every worker's education must entail some form of HSR-specific training or education. Unfortunately, our model does not enable us to specify training or education curricula that are appropriate for each position, although the bulk of this specialized education and training will spring from the HSR technologies that we explored earlier that are linked to emerging trends during the development of the CHSR network.

Table 17 summarizes the education needs associated with each of the phases of the project, identifying percentages that show areas of high demand for specific levels of education attained, with further exploration of HSR-specific needs of the workforce recommended.

Table 17. Education Need, by Project Phase, 2009–2025 (As a Percentage)

Phase	Design	Build Management	Build Construction	Operations and Maintenance
Less Than High School	0%	9%	28%	13%
High School	1%	21%	46%	42%
A.A./A.S.	1%	6%	3%	9%
Some College, No Degree	2%	15%	13%	24%
B.A./B.S.	61%	34%	9%	9%
M.A./M.S.	30%	13%	0%	3%
PhD	5%	2%	0%	0%
Total	2,214	18,954	202,741	32,184

Peak Period Findings

This section has identified a major period of demand for personnel that occurs over a four-year period under the 2009 BP. By definition, the peak period of 2013–2016 has the highest level of labor demand over the life of the CHSR project, according to the projections of the Phase 1 build. As might be expected, this period represents the middle of the build-out of the project, and it precedes operational and maintenance training (although some of the latter activities may begin around this time frame). During this peak period, there

is an estimated four-year period of demand for over 175,000+ worker years. Figure 17 focuses on the education backgrounds projected to be required during that time, for this workforce. Approximately 71 to 75 percent of the total workforce during the peak period will need trades training and/or apprenticeship certification. Trades training may include both training certification for laborers in new-construction practices and in emerging HSR technology/construction practices.

Sixteen to 19 percent of the workforce during the peak period will require education that takes place at the community college level, and many of these workers will receive training in emerging practices. These emerging practices include managerial construction training (i.e., forepersons and lines persons) as well as very specific training such as drilling/bulldozing/pile driving. This training can be expected to occur through trades and/or community colleges or partnerships to administer such specialized training. Thus, community colleges will be critical in providing short-term specialization training or certifications for those who already are involved in trades managerial roles.

Finally, at the peak period, 6 to 13 percent of the total workforce will require higher education and training (B.A./B.S., M.A./M.S., or PhD level). These positions are primarily related to engineering and will function as quality-control assurances as well as engineering/managerial roles throughout the peak period. Construction managers, architects, and industrial engineers further constitute the workforce holding bachelor, master's, and PhD degrees. Figure 17 summarizes the estimated training demand, during the four-year peak period. As a rule of thumb, for every professional/personnel educated at the community college level or above (i.e., higher education), there is the need for three trained laborers (high-school and below).

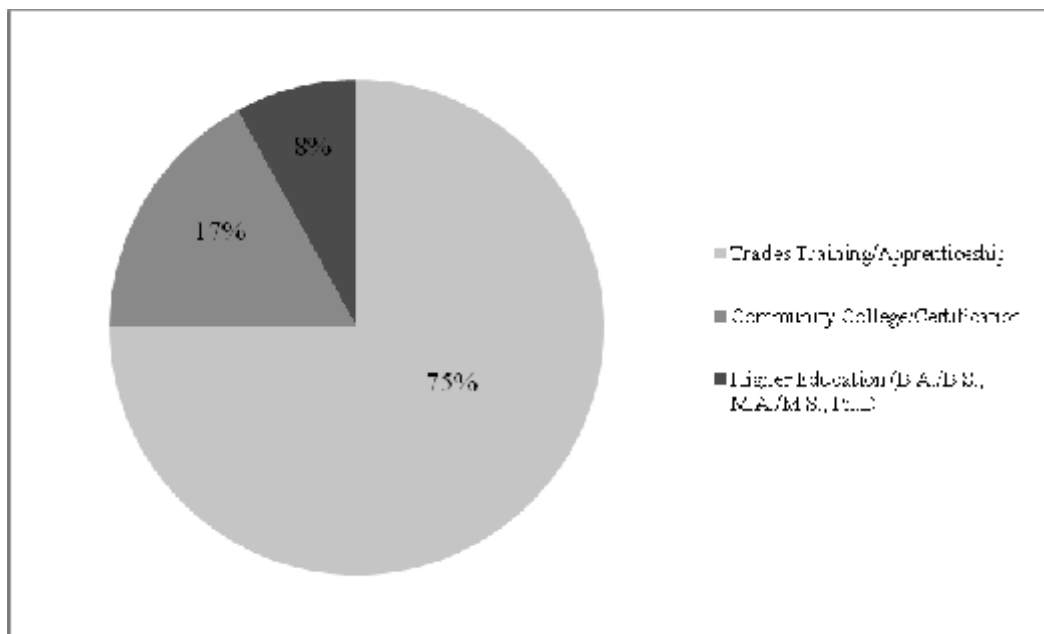


Figure 17. Training, Community College, and Higher Education Need, During Peak Period, 2013–2016

Training Needs at Peak Period

This study has demonstrated a vast need for professionals and laborers who will create extensive demand for workers with various levels of education. Virtually no prospective employees currently have rail expertise and training, let alone HSR-specific experience, and therefore need will arise not only from the education and training backgrounds we have identified but also from the specialized training and education needs related to HSR. Our data enable us to broadly identify the need for such training in key types of positions, by levels of education, training, and experience. We assume that linkage between emerging HSR technologies and education is the basis for much of what needs to be taught and learned. A significant influx of education and training needs in HSR technologies that the state cannot currently provide will occur.

Specific Training and Education Implications, by Program Phase

Design Implications

The design personnel, at the peak period, will constitute less than one percent of the total workforce. Although small, this group will be elite, highly specialized, and essential in the compliance of the build to HSR specifications. Currently, this is a service that is being administered by Parsons Brinkerhoff, who is responsible for the program management deliverables of the project. The response in terms of education will need to address the need for educating civil engineers, engineering managers, construction managers, mechanical engineers, and architects. Each of these positions require a completed degree, B.A./B.S. or higher. Thus, concentrated effort on the pursuit of transportation-focused M.A./M.S. and PhD programs that create instructors is probably necessary to prepare the future teachers and designers of the HSR technology systems, and to allow for firms to concentrate on the recruitment of qualified BA-holding civil engineers.

Build Management Implications

Transportation-focused construction managers must be prepared; 6.16 percent of the personnel/professionals needed during the peak period will be involved with this managerial role. This implies a specific environment (community college or university) to be designated as a training zone for the construction managerial positions, in alignment with both controlling the dissemination of technology-related knowledge while also institutionalizing managerial construction practices into the community college and university levels. Second, training the managers needed for these positions is critical, both in quantity and in terms of HSR-specific training/education.

Build Construction Implications

The build personnel, who constitute 85 to 93 percent of the personnel affiliated with the education peak period, will need vast amounts of training support to prepare a workforce estimated to be over 130,000 PY during this period. This can be considered the “construction surge,” and will entail hiring construction laborers, construction carpenters, emergency management specialists, pump operators (except wellhead pumpers), earth drillers (except oil and gas), operating engineers and other construction equipment operators, continuous mining machine operators, electricians, reinforcing iron and rebar workers, and structural iron and steel workers, and many more.

HSR-specific training will be required for an estimated 75 percent of that workforce with a high school diploma or below. In addition, an estimated 16 percent will hold degrees at the A.A./A.S. level or have some college course work, and 10 percent will hold a B.A./B.S. degree. The trades apprenticeship/training and community college infrastructures will need to help prepare the many workers who will complete activities during that time frame. The B.A./B.S. level construction labor force (estimated to range from 6 to 20 percent of the total) may potentially integrate their academic capacity into existing construction practices, along with HSR-specific course work and/or training.

Operations and Maintenance Implications

Operations and maintenance personnel require specialized, highly detailed, and technology-related training that may warrant a concentrated focus in the development of a modern HSR curriculum. This may coincide with a second, smaller peak period concentrated around 2020–2021, but beginning as early as 2013–2016 based on the 2012 BP. During this period, an estimated 4,020–4,950 individuals will require training in compliance with emerging mandates about the training protocol for HSR systems by the FRA and others. All nations that have signed a memorandum of understanding with the CHSRA as well as an extensive list of private providers are in the position to sell the proposed operations and maintenance practices to the CHSRA; however, the true challenge lies in the adaptation and retention of such knowledge and information. A central “learning center” housed at a university, community college, or trades training center might appropriately serve as a central location with the responsibility and mandate to conduct the training needed as well as disseminate the operations and maintenance practices and protocol through university and community college satellites.

We now will explore the current rail-focused education capabilities in the United States, identifying shortages in the capability to train the needed HSR workforce identified in this section. It will relate the immense need for training and education documented in this section and the general need for greater technological capacity identified earlier with the existing capacity of the California education system.

The New 2012 Business Projections

The new BP 2102, with a longer project delivery period (into the 2033 period), segmented project delivery, larger quantities of labor-intensive activities (contributing to higher costs), and a general reassessment of unit prices at a more fine level, has significantly increased the labor need to well over 333,000 direct PY over the life of the project. This has the general impact of requiring a more construction-oriented labor workforce over the entire project.

III. EXISTING CAPACITY FOR PREPARING THE HSR WORKFORCE

Large capital projects can create a heightened demand for skilled and knowledgeable labor that may then feed into a series of innovative outputs via university–private partnerships in the form of spin-off technologies. One essential key to timely construction, operation, and maintenance of the new system will be appropriate associated training at the many levels of demand created by a specialized, higher speed system. For example, our findings document the need to train well over 40,000 personnel/professionals for a peak period of four years (2013–2016).

For the continued development and eventual success of HSR, California community colleges and universities may need to serve as pivotal training and research mechanisms to meet workforce need and solve structural challenges as they arise. In addition, because the majority of the HSR construction workforce and much of its operating staff will be laborers, worker training and apprenticeship programs also will play critical roles. This section will address the existing capacity for rail training and education in California—or more, accurately, the lack thereof. It also looks to other states and countries for anecdotal examples of how the training and education system may best be adapted to meet the projected need for a skilled and knowledgeable HSR workforce.

COMMUNITY COLLEGE CAPACITY

The community colleges, which can be expected to address the education/training needs of roughly one fifth of the estimated workforce during construction of the CHSR network, represent a complex and adaptive network of community-based education and training providers. California community colleges together make up the largest higher education system in the nation. The system is comprised of 72 districts and 110 colleges, and enrolls more than 2.9-million students. Community colleges provide basic skills education, workforce training, and courses that prepare students for transfer to four-year universities. The colleges also offer opportunities for personal enrichment and lifelong learning.⁵³ Based on its breadth and capability to adapt to market demands, the community college will have a large capability to change based on learning needs of the CHSR network. This includes the ability to create HSR courses, certificate programs, and potentially A.A./A.S.-level HSR-focused degrees.

Community colleges also have the ability to train managerial positions, such as those needed throughout the HSR system build. Assuming a responsibility for the community colleges to function to “train the trainers,” there is a network of CCs specifically set up to educate in construction management in California. Construction management training schools already exist at the community college level, such as those at the College of San Francisco, College of the Canyons, College of the Desert, Diablo Valley College, Fullerton College, Hartnell College, Modesto Junior College, and Laney College.

More prevalently, in partnership with trades partners, California's community colleges often serve as a forum to provide certificate-achieving trades accreditation. These programs include community college based training in at least 15 community college/trades shared disciplines, including carpentry, electrical training, heating, ventilation and air conditioning, plumbing training, air conditioning, solar energy, construction trades training, electrical,

refrigeration, environmental control technology, pipefitting, and plumbing training programs. Aspects of some or all of these types of programs may possibly be adapted to HSR-related topics.

TRADES TRAINING CAPACITY

Trades will certainly be a major partner in the construction of the CHSR network. Estimated in our project to represent roughly the training locus of three fourths of the total workforce, trades training and education will be a critical element in support the workforce needs of the CHSR build. Generally speaking, trades training is administered regionally by local trades associations, and there is an extensive trades-based training support network provided by various regional building and construction trades councils. These programs must be registered with the California Division of Apprenticeship Standards, which cover many—if not all—of the recognized U.S. Department of Labor Office of Apprenticeship programs. These programs offer long-term training, “Earn While You Learn” stipend and pay during training programs, full-time employment with career placement, with opportunities to pursue college credit and/or an A.A./A.S. degree during the period of employment.

Supplementing community college/apprentice partnerships that encompass generalized training, these programs also can be tailored to deliver very specialized training specific to rail needs. An example of this is seen in the San Diego Community College District, which has partnered with local trades affiliates to train light rail vehicle lineman in a three-year apprenticeship program. Currently, the trades systems are upgrading to modernize trades training in alignment with emerging California state “green economy” objectives. The California Apprenticeship Council recently approved integration of environmental (i.e., “green”) components into industry training criteria for the building construction trades apprenticeship programs. Starting in 2011, all construction apprentices in California will receive instruction on green building practices as a component of their training to satisfy emerging green-building standards. Thus, the trades training system has demonstrated preparedness and willingness to upgrade and prepare for the needs that are created in the construction of the CHSR network.

HIGHER EDUCATION CAPACITY

As we consider the state of rail education in the United States, the extent to which it is at best piecemeal and insufficient even to current needs cannot be overstated. To date, moreover, no institution is responding on any significant scale to the need for instruction and research in the more specific field of HSR. This is perhaps best illustrated with the fact that only a handful of college professors in the nation specialize in rail education; however, a number of programs situated in a variety of settings may comprise either models for future development or the basis for expanded capacity.

Existing rail-related education in the United States is presently delivered by one or more of four mechanisms: (a) colleges and universities, (b) rail industry administered trainings, (c) fixed location private rail academies featuring test railroads, and (d) independent “road shows” led by consultants. What is to be determined is a workable balance of expanded education responsibilities of governmental bodies, private industry, and academia in preparing a generation of workers knowledgeable in rail construction, management, and engineering principles. Although this exploratory study will offer no definitive answers, a review of existing resources and capabilities is included in this section.

The most comprehensive examples of university training programs include a few rail concentrations within civil engineering programs and advanced degrees in railroad engineering, and those that actively conduct rail research. However, more commonly, transportation engineering concentrations may feature a limited number of courses or labs addressing rail specifically. A small number of universities offer short courses (modules), typically two to five days in length, which are contracted by the railroad industry to address specific technical-knowledge shortfalls. Universities and community colleges may partner with industry and/or unions in administering rail operation training and internship programs.

Industry-administered training generally takes the form of hands-on internships. Succession planning mechanisms present within the industry include peer mentorship, contracted professional development, and education stipends for employees seeking degrees in management.⁵⁴ A minute number of private rail academies offer intensive sessions throughout the year to individuals seeking certificates in conducting and locomotive engineering (at hefty cost to participant).⁵⁵ Institutes such as Modoc Rail Academy (California) boast high placement rates for graduates. Independent consultants with extensive rail experience offer hands-on instruction in mechanics of Class 1-5 railroads, including exam preparation. These services are contracted by rail operators.⁵⁶

At the California state level, apprenticeship training programs for a variety of specific jobs and skills that may be related to HSR (or could be fitted or created to support it) are routinely offered, including such job categories as pile driver, surveyor, and machine operator. Specifically, the California Apprenticeship Council lists well over 40 specific apprenticeships, delivered and overseen by seven regional Apprenticeship Coordinators Associations.⁵⁷

A uniform characteristic of these mechanisms is the education content catering to freight railroad operation and maintenance. The United States continues to be among world leaders in freight operations, with industry typically devoting 15 to 20 percent of annual capital investment to the maintenance and improvement of freight capacity,⁵⁸ and it is only sensible from a business perspective that training offered for profit addresses this increasing demand. However, they are not necessarily geared to the technological needs associated with a new HSR passenger network; because they are private and profit-oriented enterprises, they instead focus on their core freight business.

Questions remain about how to obtain the information needed to design and construct the complex HSR system: Do any of these mechanisms currently have significant HSR knowledge or the capacity to acquire and disseminate it? Our review suggests that in terms of technology transfer and research capacity, existing relationships, and costs, (a) colleges and universities and (b) the rail industry are the most likely candidates.

On an extremely limited scale, some American-university professors are beginning to develop partnerships with professors at institutions in HSR-equipped nations, such as the partnership between Dr. Chris Barkan at the University of Illinois at Urbana-Champaign (UIUC) and Dr. Tsung-Chung (T.C.) Kao at National Taiwan University, and parts of Amtrak's operations (e.g., the University of Tennessee contracting its course on FRA 213 Subpart G detailing higher speed track inspection specifications to Amtrak's Acela), and are receiving research grants directly from industry.

Private industry also has been successful in developing partnerships with other nations' research institutions and firms. With respect to the CHSR project, Parsons Brinkerhoff has worked with foreign entities to receive input from Japanese and European high-speed train engineers to confirm the CHSR approach to design and operations planning,⁵⁹ and the list of private firms with the capability to provide such HSR-connected services is extensive. Further, private-industry giants such as AECOM finance research products that acknowledge the need for greater investment in rail education and promotion in public schools in addressing anticipated personnel shortfalls, particularly in the area of signaling technology engineers.⁶⁰

University and industry are not always mutually exclusive in function, in that the two types of institutions interact in a number of ways in exposing students to the elements of rail training. This makes sense, as firms regularly identify potential candidates throughout their time in school, both through project research and existing industry-specific social channels such as industry-sponsored events. This overview will point to areas of crucial overlap between university and industry, with the hope that best practices can be explored in California, if not elsewhere across the nation.

THE ROLE OF UNIVERSITIES

By long-established policy and practice, "transportation engineering" is nearly synonymous with "highway engineering."⁶¹ The Federal-Aid Highway Act of 1956 served as a catalyst for an institutionalized process of research, innovation, and education dissemination pertaining to the construction of roadways. Evidence of this may be seen in the timeline of development of (now) top-ranking civil engineering and transportation engineering (concentration) degree programs⁶² and the growth of their partnerships with entities such as Caltrans.⁶³

Presently, a national network of University Transportation Centers (UTCs) are partially funded by the U.S. Department of Transportation's (USDOT) Research and Innovation Technology Administration (RITA). Centers loosely organize under research themes, freely associate with one another, conduct basic and applied research, and facilitate technology transfer—their funding and tier designation contingent on the capacity to perform these functions. As of fiscal year 2011, the UTC program is funded through RITA allocations from the Federal Highway Administration (\$69.1 million) and a reimbursable agreement from the Federal Transit Administration (\$7.6 million).⁶⁴ Further demonstrating a culture of incentive for highway research and development, federal investment in highway research and development from fiscal years 2009–2011 was \$412 million annually.⁶⁵ While this notably includes research in Intelligent Transportation Systems (under the SAFETEA-LU extension) for \$110 million,⁶⁶ and that research will be pivotal in connecting other modes to the HSR system, federal investment directly in rail research and development was \$40 million or less annually over the same period.

Perhaps the foremost transportation research entity in the United States is the John A. Volpe National Transportation Systems Center in Cambridge, Massachusetts (Volpe Center). It operates as a fee-for-service research entity, serving both the USDOT and industry, featuring a Rail and Transit Systems Division of engineers with expertise in various rail technologies, including HSR.⁶⁷ Due to its unmatched research capacities, the Volpe Center will presumably continue as a prominent partner of the FRA as it develops

safety, technology, and inspection standards of Class 5-9 railroads,⁶⁸ pertaining to HSR research and development.

However, the most recent FRA budget submission includes \$30 million specifically for HSR research and development and support functions, including \$500,000 toward the creation of the Rail Cooperative Research Program (RCRP). Originally authorized by the Passenger Rail Investment and Improvement Act of 2008, the RCRP was scheduled to be administered by the TRB beginning Spring 2011.⁶⁹ Like other TRB Cooperatives, the RCRP will accept research proposals from public and private entities (e.g., railroads, states, technology providers, and university researchers), guide research questions, and disseminate results via online databases. The RCRP aims to be a more efficient nexus of rail research activities than the less directly applicable Innovations Deserving Exploratory Analysis (IDEA) program funding early stage HSR research, which ended in 2008.

The FRA has indicated that areas of priority HSR research and development to be funneled through this research cooperative include: wheel and track interaction, improved energy efficiency and reduced emissions, advancements in PTC systems, and display configurations for high-speed locomotives. Nevertheless, the RCRP is in a state of pre-infancy and has yet to fund a single research project. For its part, the FRA has begun to move forward with planned efforts to fund HSR specialized research, relying heavily on the TRB IDEA Program and other organizations, as the primary means through which to conduct HSR research.⁷⁰

In addition, AREMA Committee 17 on High-Speed Rail Systems, representing rail industry interests and university professors from Michigan Technological University and the UIUC has spearheaded the Railroad Engineering Education Symposium (REES). The REES provides an online forum for university professors to post presentations showcasing rail fundamentals and mechanics. The interface is still in its infancy, and the few materials presently found in the REES drop box primarily pertain to freight.

Overall, AREMA Committee 24 serves as a nexus for American-university professors and industry executives to “promote the need for specific railway engineering education among [the academic] community. They are also responsible for developing programs encouraging student interest in railway engineering and the continuing education of engineers employed in the railway industry. This committee is also dedicated to adding value to the members by providing a working forum for Maintenance-of-Way training professionals to develop and exchange ideas to increase safety, quality and productivity; thereby effectively addressing the challenges of the industry.”⁷¹

The Association of American Railroads (AAR) partially sponsors a series of affiliated laboratories—UIUC, Texas A&M (Texas Transportation Institute), Virginia Tech, and others—which serve as a point of collaboration between academia and specialists of several fields (e.g., electronics, computers, etc.) to conduct applied rail research projects contracted by AAR.⁷²

In sum, however, these existing efforts are quite modest, and tend to be only nascent with respect to HSR research, particularly regarding workforce development. Compared to the magnitude of the needs outlined in this report, the lack of an established education and training in HSR infrastructure in the United States poses a major challenge.

U.S. UNIVERSITY PROGRAMS LEADING IN RAILWAY ENGINEERING TRAINING AND RESEARCH

The ostensible epitome of rail education in the United States is the UIUC. Like most other U.S. universities, the UIUC believes in broad-based civil engineering education and offers transportation as a concentration at the undergraduate level. Four standing courses in railroad engineering address system planning and design, signaling technologies, and principles of construction and maintenance. Advanced degrees are offered in railroad engineering, and abundant research opportunities are afforded for graduate students. The school hosted the 2010 Joint Rail Conference on High-Speed and Intercity Passenger Rail, and annually hosts the Railroad Environmental Conference. The faculty and students actively participate in various conferences, job fairs, and other regular placement interaction with industry; relationships are being thoroughly established with the AAR and individual rail companies such as the Canadian National Railway (CN), which funds rail research fellowships at the UIUC.⁷³

The UIUC is the first U.S. university to offer a (single) course in HSR engineering, taught by program director Dr. Chris Barkan and Dr. T.C. Kao, National Taiwan University Railway Technology Research Center Director. The course covered HSR design differences such as: “the subgrade, track system, motive power, rolling stock, traffic control, power distribution system, traffic control and station design ... as well as the planning, economics, construction, operation, maintenance, management and other principles of HSR systems.”⁷⁴

Research activities at the UIUC are coordinated through the Rail Transportation and Engineering Center (RailTEC), which is the formal mechanism through which Barkan and civil engineering colleagues collaborate with a variety of UIUC professors (e.g., other engineering disciplines, business, and economics) as well as industry giants CN, BNSF Railway, Hanson Professional Services, Norfolk Southern, and CSX Transportation.

As an example, if the only existing one, of a contemporary presentation of the potential of established relationships between government, industry, and academia, Barkan and colleagues are conducting a feasibility study of the high-speed line currently planned for the Chicago region. The study will include cost/benefit analysis in offering corridor location recommendations, including ridership estimates.⁷⁵

The institute also organizes seminars and short courses on contemporary topics for the benefit of students and industry employees. RailTEC research activities include effectiveness of real-time monitoring systems, best practices in transportation of hazardous materials, and effectiveness of Lean Management methods on terminal performance. Of note, the last is an emphasized skill set in German operator Deutsch Bahn’s postings for high-speed carrier ICE management positions.⁷⁶

Another university making strides in rail education is Michigan Technological University (MTU). It hosts an annual “Railroad Night” featuring panels of experts from carriers such as Union Pacific (UP), CN, and Amtrak. This partnership exemplifies the potential merging of university, rail firms, and governmental interest in developing rail infrastructure. The Rail Transportation Program is not a separate degree program, but includes term-length courses entitled “Introduction to Railroad Engineering” and “Railroad Track Engineering and Design.” MTU also recently received a grant from CN to establish the CN Rail Transportation Education Center.

International relationships also are being built by Dr. Jerry Rose at the University of Kentucky. Rose's research interests include areas pertaining to trackbed design, on which he has collaborated with Technical University of Lisbon researchers. A recent research output discussed international approaches to using asphalt (bituminous) in ballastless trackbed design and reported improved performance in Asian and European HSR systems at different layers of asphalt thickness.⁷⁷ Further, Rose teaches courses entitled "Railroad Facilities Design and Analysis" and "Railroad Operations Management" in the Civil Engineering Department. The former details best practices within the DBOM sequence, and the latter is, by and large, a railway-specific logistics course.⁷⁸

These three universities represent the most comprehensive models of rail education in the United States. The leaders of these programs have established a network among themselves (Many are involved in AREMA Committee 24 on Education and Training), along with international university professors and with industry partners, and they are offering course work strictly pertaining to rail. This is a series of conditions that no California institution approaches. Even taken as a group, however, their efforts represent only small percentage of the potential need for creation and dissemination of passenger rail knowledge and expertise, especially at the higher echelons of speed in the 220-mph range.

OTHER APPROACHES FROM U.S. UNIVERSITIES

More commonly, U.S. universities offer modules or short courses contracted by rail companies and effected governmental partners, but many of these also are open to individuals. Topics range from design basics applicable to all railroads, such as grade crossings and structural components of track as well as railroad management. Training is usually a combination of classroom and fieldwork, but may be strictly theoretical in cases of trainers traveling to conference centers or other neutral locations. Similar to the "road show" approach discussed earlier, a number of universities serve as institutional, on-demand consulting entities.

A rare example of fixed programming is Michigan State University's (MSU) Railway Management Program. The Certificate Course is administered in four one-week segments, offered in four consecutive months. Each week takes place at a different facility in the United States, beginning with historical and trend analysis at MSU's campus in Week 1, relocating to Pueblo, Colorado in Week 2 to learn physical aspects of locomotives and track at the test track operated by (AAR subsidiary and FRA subcontractor) Transportation Technology Center, Inc., and so forth. The intensive program includes topics in rail finance, emergency response, communications and signaling systems, scheduling crews, and best management practices. The curriculum was developed by American Short Line and Regional Railroad Association, AAR, and FRA consultants, the content catering to Class 1 and Class 2 railroads.⁷⁹ While the program includes a theoretical overview of issues affecting the future of the industry, HSR specifications are not addressed in this model, and inadequate facilities exist at present to combine theoretical and practical course work to this degree. Notably, one plan for the California build-out is for the Central Valley segment to be incrementally upgraded to true high speed and serve as a regional test track as the system expands.⁸⁰ If so, fieldwork components of extensive training modules such as the MSU program may be feasible in HSR training.

A slightly more common model is for short courses to be offered at regular intervals and/or as needed at satellite conference centers such as through the University of Wisconsin-Madison, which offers a series of two- or three-day courses for Professional Development Hours or Continuing Education Units targeted to those in rail operations and governmental planning, at a fee of \$1,095-1,195 per participant. Course topics include track structure (ballast, sub-ballast, ties, etc.), signaling, and railroad safety.⁸¹ Like the UIUC, the University of Wisconsin-Madison also works with industry partners to present programs tailored to the needs of participants, including traveling to the industry site.⁸² These courses do not presently address HSR systems, focusing instead on existing passenger and light rail operations in the United States. However, this professional development module format could potentially be adapted to HSR-specific topics, as is the case through the University of Tennessee-Knoxville.

The University of Tennessee offers a 4½-day course called “Railroad Track Inspection and Safety Standards for High-Speed Rail.” This course is an expansion of another module offered by that university in standard track inspection practices, incorporating tighter limits, higher standards for functionality and number of cross ties, and lower allowable chord-offset values of Class 6 and above railroads, insofar as defined in FRA Part 213, Subpart G. The course is currently contracted as needed by Amtrak, and can be administered to those with little prior knowledge of track inspection practices.⁸³ The University of Tennessee-Knoxville also offers modules (assuming some previous engineering training) covering conventional rail topics such as basic track and railway bridge maintenance, and track geometry and design consistent with current AREMA standards.

The University of Tennessee-Knoxville also features the University of Tennessee Center for Transportation Research, the regional University Transportation Center, which conducts research under the theme of “Comprehensive Transportation Safety,” regularly coordinating the research agendas of partnering Southeastern Transportation Centers—those UTCs within USDOT Region IV—by calling for proposals, verifying they are within the theme, facilitating the RITA submission process, and publishing products in the *Journal of Transportation Safety and Security*. This level of communication and coordination is not currently demonstrated by California research institutions, and the future of the overarching UTC structure is uncertain as of Summer 2011.

The Center for Transportation Research also has entered collaborative agreements with Beijing Jiaotong University (China) to share research and co-sponsor conferences, internationalize the University of Tennessee-Knoxville Laboratory for Driving Simulator Studies (automobile simulator), and exchange students and professors in various areas of transportation engineering.⁸⁴ The arrangement seemingly pertains predominantly to other areas of transportation studies, but represents an American-university partnership with an institution notable for its rail degree programs.

SUMMARY OF EXISTING RAILROAD HIGHER EDUCATION IN THE UNITED STATES

While this is by no means a completely comprehensive compilation of rail course work and programming in the United States (Courses are or also have been conducted at North Dakota State University, South Dakota State University, and the University of Maryland.⁸⁵), this overview provides for practical purposes the significant elements or training mechanisms found in U.S. universities:

- A limited number of railway engineering specific course work falling under civil engineering degree programs.
- Relationships between several U.S. professors and professors of foreign research institutions to facilitate understanding of HSR concepts.
- Examples of regional cooperation in research (spearheaded by a regional UTC).
- Intra-university level cultivation of (not strictly engineering) faculty expertise.
- Collaboration with industry in offering specialized topics in short-course format at locations easily accessible to industry.
- Collaboration with both industry and international partners in hosting rail conferences and facilitating contact and placement opportunities for students.

In sum, the number and amount of existing university efforts directed at rail education are at best sparse, and that directed at HSR is virtually non-existent, although some evidence of growth and development is available.

INDUSTRY INTERNSHIPS AND ON-THE-JOB TRAINING

Whatever its final role, some elements of training and certification will need to come through CHSRA or its successor organization. While CHSRA has isolated the desired training time frame for several job titles, the degree to which CHSRA will be involved in the actual crafting and dissemination of training below the baccalaureate level is still to be determined, as are any certification mechanisms and associated levels of CHSRA-administered training.

By contrast, in many European HSR nations, personnel requiring equivalent to certificate or A.A./A.S.-degree-level training are often trained in trade school or “academy” settings⁸⁶—entities often separate from state-run operators, but recognizing baseline standards for certifications and Technical Specifications for Interoperability adopted by the European Commission in 2002.⁸⁷ In other cases, rail operators such as SNCF self-administer year-long conductor training.⁸⁸ Currently, Amtrak requires likely equivalent “Passenger Engineer Trainees” from no previous experience to undergo “7-10 weeks classroom and field work while headquartered at Amtrak’s Training Center in Wilmington, DE; followed by extensive qualifying and on-the-job training associated with the Crew Base for which hired.”⁸⁹

INTERPLAY OF UNIVERSITY AND INDUSTRY

This university-to-firm connection is extensively represented in the intern/mentoring relationships that Union Pacific (UP) actively uses for recruitment purposes. UP actively recruits college students to internships in areas of corporate audit, finance and accounting, information technology, and marketing and sales. UP also partners with universities such as the UIUC and MTU (via campus visits/conference presence) to place engineering students in the Engineering, Mechanical and Transportation departments.⁹⁰ This scheme of division of management preparation also is found within Amtrak's Professional Development Program.⁹¹ In the case of UP, interns may either alternate semesters between full-time, hands-on work experience and full-time schooling or gain field experience part-time throughout the school year. Amtrak's program is a 12- to 18-month entry-level commitment, also drawing participants from interaction on university campuses.

Such mechanisms for career development and succession planning are prominent within the rail industry. For those with bachelor's degrees, UP offers an accelerated Operations Management Program combining fieldwork (similar to the internship) with classroom instruction as to the history, values, and strategic goals of UP. CN offers a variety of management, leadership, and business courses in addition to job-specific task demonstrations, even offering education assistance for those qualified to pursue Executive Master's in Business Administration programs.⁹²

Key practices from industry include:

- For those entering industry with no previous experience, contemporary mechanisms centralize fieldwork and course work under training hubs.
- Relatively short periods of on-the-job training suffice at the certificate level.
- Succession planning practices exist to transition high-performing personnel into management roles.
- Willingness to collaborate with university via campus visits and conference presence.
- Research is largely deferred to university centers.

OTHER COUNTRIES' RESPONSES

While a complete detailing of the education and research mechanisms the world over is beyond the scope of this project, other nations provide anecdotal illustrations on how HSR training, education, and research might successfully be provided. Numerous social and political factors must be taken into account when contemplating other nations' approaches, such as degree of acceptance of vocational alternatives and public versus private financing models dictating the level of governmental investment in rail training. For instance, whereas China is a heavily nationalized model in which the university serves as an extensive education dissemination and research mechanism, much of Europe relies on trade-school-type entities or training administered directly by rail companies to meet its workforce needs while leaving research to universities and their partners.

China

The Chinese education system is highly centralized and has practiced pointed investment of resources in the post-Mao era. “Key Universities” (or “Key Institutions” or “Key Schools”; a terminological debate continues around this concept)—those institutions contributing to technological and infrastructure development—remain under the direct administration of the Ministry of Education.^{93,94} Universities tout “Key Disciplines” at either the provincial or the national level, in areas such as “Road and Railway Engineering,” “Bridge and Tunnel Engineering,” and “Traffic and Transportation Planning and Management.”

In addition to prescription to Confucian ideals, emphasis in military philosophy,⁹⁵ and labor typically included as an element of longer school days, China also has placed great emphasis on English language communication skills. At present, China graduates “more English-trained engineers than the United States.”⁹⁶

Beijing Jiaotong University provides an example of how rail (as a subcomponent of traffic and transportation) is incorporated into Chinese universities at as high as the departmental level. In a step up from the American model of Civil Engineering degrees with Transportation concentration, China offers Transportation Engineering degrees with Rail concentrations beginning at the undergraduate level. Figure 18 illustrates the three-tiered learning, in which a student receives specialization in a National Key Discipline, a school specialization, and a within-departmental specialty.

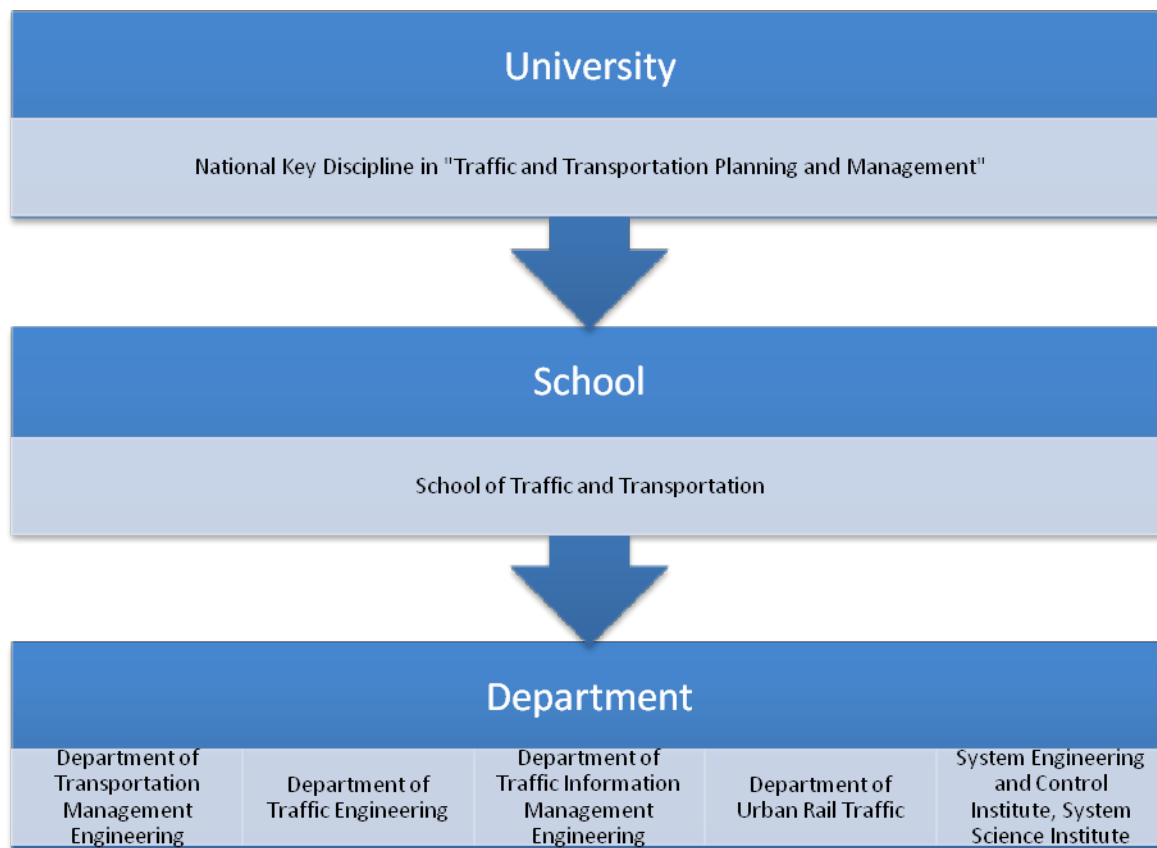


Figure 18. National Key Discipline, School Specialization, and Department Specialization in Chinese Transportation Education Structure

Long-established railway institutions such as the Southwest Jiaotong University Transportation Institute may confer bachelor's, master's, and doctoral degrees (under the broader heading of Transportation Engineering or Transportation Management). A Transportation Engineering program includes courses such as "Fundamentals of the Railway Line," "Regulations of Railway Technical Operation," "High-speed Railway," "Railway Transport Engineering," "Railway Station and Terminal Design," and "Train Operation Organization."

A final notable Chinese railway institution is the China Academy of Railway Sciences (CARS). A much larger functional equivalent of the Volpe Center, CARS is a nationalized entity for research and development. Further, it hosts conferences in partnership with the Ministry of Railways. "It has established multi-level and multi-channel communication and cooperation relations with the International Union of Railways, International Heavy Haul Association, more than ten countries and world famous enterprises of the United States, Japan, Russia, France, Germany, Sweden, Poland, Korean etc., in various forms such as mutual visits of experts, establishment of teamwork relations, hosting international academic conferences, inviting visiting professors, long-term technical cooperation as well as products import and export."⁹⁷ Interestingly, CARS also may confer master's and doctoral degrees (similar to the British research-based master's degree earned through extensive field research). CARS is home to over 3,000 researchers, of whom 69 percent are technical personnel. Thus, with extensive institutionalized mechanisms through which to disseminate rail and high-speed rail knowledge and education, China represents the existing paragon of rail education, including the following key features:

- Degree programs in Transportation being offered at the undergraduate level, with Rail as a concentration or specialization;
- Efficient designation of (and corresponding investment in) nationally recognized university centers according to key competencies; and
- Nationalized research and development facilities.

More typically in Asian nations, railways are at least partially privatized, and railway research is conducted in part by industry-sponsored research institutes.

British University Model

Another country displaying a model of governmental support of collaborative, but more clearly delineated, efforts is the United Kingdom. While the university program or concentration content of the United Kingdom does not necessarily match that of China, the British government recognized the need to finance a number of studies pertaining to HSR-specific challenges for the 2003–2010 period, which were performed by experts at various British universities falling under the umbrella organization Rail Research UK. The consortium of British universities was funded by (governmental entity) the Engineering and Physical Science Researches Council (EPSRC) until 2010. Research was conducted in the broad categories of Engineering Interfaces, Whole System Performance, and [effects to] Users, Community, and Environment. Research projects are no longer funded by EPSRC but instead by the Rail Safety and Standards Board, a non-profit promoting consensus building, adoption of best practices, and shared standards within Great Britain and greater Europe.⁹⁸ Research projects also are funded by Network Rail, the government body

owning British rail infrastructure and managing partnering private-sector train operating companies.⁹⁹ The consortium of British universities conducting rail research maintains an active online nexus as the Rail Research UK Association.¹⁰⁰

British Program Content

There also are notable standout programs in the United Kingdom, and the University of Birmingham is the leading institution for rail education there. It is home to the Birmingham Centre of Railway Research and Education, which offers a research-based master's (M.Res.) in Railway Systems Integration and a taught master's (M.Sc.) in Railway Systems Engineering. Various other universities' civil engineering and transport planning programs offer rail courses or course components. Most commonly, a university features one to three researchers who specialize in rail topics and lead PhD research projects in technical areas. Each university in the organization has research themes that may be applicable to rail transit, with some more directly pertaining to HSR. Research themes at respective British universities include:

- Social environmental impacts, transportation policy, and market research.
- Railway technology, infrastructure design and construction, and public transport operation/safety, project management.
- Technologies for transport monitoring and systems management (i.e., carbon emissions, structural degradation, energy research, smarter interfaces), travel behavior, and transport planning.
- Engineering interfaces, modeling for high-speed vehicles, and development of virtual test track/simulation software.

Crafted under these broader areas or themes, contemporary research topics include impacts of HSR connectivity on various development plans,¹⁰¹ ridership modeling, and the effects of ballasted track on high-speed rolling stock.¹⁰²

Similar to the U.S. model, but at a more advanced and firmer stage of partnership, most British universities have their own industry and international collaborators. For example, Network Rail has a working relationship with Sheffield Hallam University, which offers a Foundation Degree in Railway Engineering that is suitable for both those already employed within the rail industry and those wishing to enter directly from secondary school. The Foundation Degree course was developed by organizations in the rail industry seeking to establish a center of excellence in railway engineering. The program combines seven months of classroom instruction with five months of field training, the latter spent in rotations through functions such as signal maintenance, track maintenance, and electrification. This program largely exists due to a shortage of railway engineers in Europe, which like the United States rail workforce is predicting massive retirements among the baby-boom generation in the near term.¹⁰³ The projected rail shortfall in the United Kingdom is severe enough that even in the present climate of conservative government and budget cuts, the British government has recognized the need to entice young entrants into the rail workforce—particularly in the area of high-speed track electrification—and is establishing a National Skills Academy for Rail Engineering in partnership with Nottingham University.¹⁰⁴

Further, some universities also offer short courses (Career Professional Development) in rail-specific topics catered to those already in industry and government entities that interact with industry, much like American universities.

Key Lessons from the United Kingdom

This observed transition from initial governmental research investment to university collaboration directly with industry may be relevant given California's current economic circumstances. Further, the identification of an area of significant need and direction by government to have a selected university develop a year-long certificate-level program to address a projected shortfall may prove to be an example of how government and university can best work together, given an adequate funding stream from the former to the latter.

Japan

Representing a model in which many research components of rail education may fall to the private partners, Japan's rail system has extensive private and university institutions with the capability to administer training and education, and supplements various training facilities that each Japan rail company operates for its employees. An example of one of those institutions is the Railway Technical Research Institute, which is the technical research division under the Japan Railways (JR) group of companies. This institution functions as a primary research and development facility for freight rail, passenger rail, and HSR. Research topics include earthquake detection and alarm systems, systems for detecting obstacles on level crossings, improving adhesion between train wheels and tracks, reducing energy usage, noise barriers, and preventing vibrations, among others.

Likened to the FRA-produced Technology Readiness Level scale,¹⁰⁵ the Railway Technical Research Institute conducts extensive research that is tiered using four different research designations, so that a certain amount of research is produced at each level of applicability. The first tier conducts research and development for future railway technology (49 projects in 2007). The second tier focuses on the development of practical railway technologies (151 projects in 2007). The third tier targets basic research on railways (84 projects in 2007). The fourth and smallest tier focuses on the development of standards and surveys (14 projects in 2007).

Outside of its research efforts, parent organization JR has previously embarked on a number of collaborative education efforts such as offering a management internship through its American partner, the University of Wisconsin-Madison.¹⁰⁶

Taiwan: From Addressing Immediate Need to Building a Lasting System

During the construction stage, the Taiwan High Speed Rail Corporation (THSRC) provided training to its engineers so that they were equipped with the knowledge of managing HSR construction (specifically the importance of communicating more exact engineering specifications). Responsibilities of construction engineers ranged from communication of HSR engineering principles to contract obligations of all parties involved. Some training took place in classrooms, and some of it occurred on-site. The appropriate training for various field personnel was identified and conducted by the THSRC Engineering Department.

The training course could be days or weeks for laborers and as long as six months for the (future) train driver.

When the construction phase was almost complete in Taiwan, a separate training unit of the THSRC was called upon to prepare operation and maintenance personnel. The operations and maintenance training unit is a continuous entity of the THSRC, educating new personnel as well as administering exams and certifications. Replication of this model in California would potentially see CHSRA (in conjecture with private partners) administer training of the length identified by CHSRA for specified occupations (likely encompassing those below the B.A. level) required for system operations.

Of note, the sequence of events, delays, and financing issues in Taiwan led to an eventual governmental takeover of the system.¹⁰⁷ However, this ultimately may have contributed to the strength of the research relationship between the THSRC and National Taiwan University and its Railway Technology Research Center. This center was established in 2009 “with five specific disciplines to promote railway education, cultivate future rail engineers, and integrate the railway resources and professionals in the universities.”¹⁰⁸

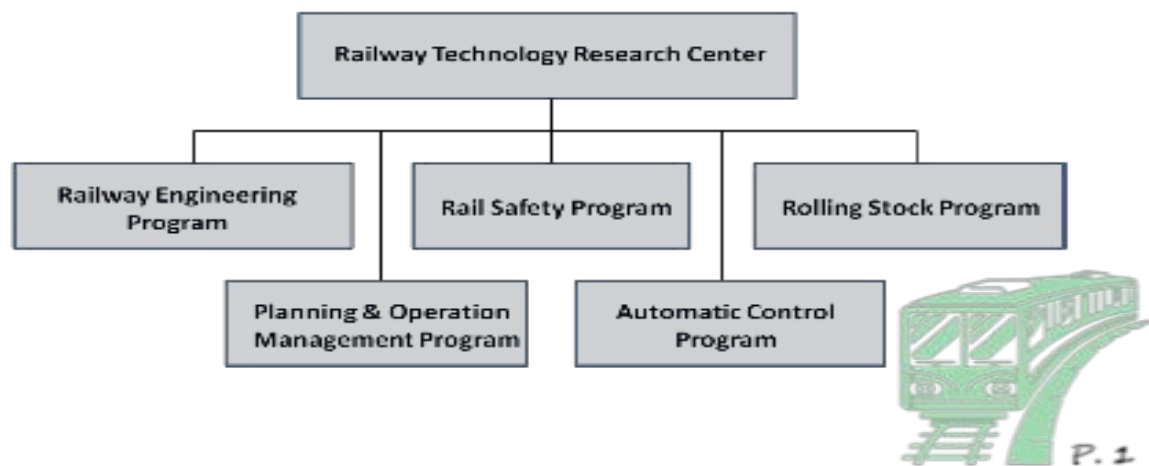


Figure 19. Organizational Chart of Taiwan’s Railway Technology Research Center

Korea

Reinforcing the theme of centralized investment, The Korea Railroad Research Institute (KRRRI) was established in 1996 pursuant to the “Special Law of National Railway Operations” and has operated as a state-funded institute throughout its existence.¹⁰⁹ The organization serves as a nexus point for academia, industry, and government, and provides the following sample of research divisions within railway research. Interestingly, in the Korean model, HSR research is granted a research and development sector separate from commuter or light rail transit research, with a unique division in place for “tilting” technologies.

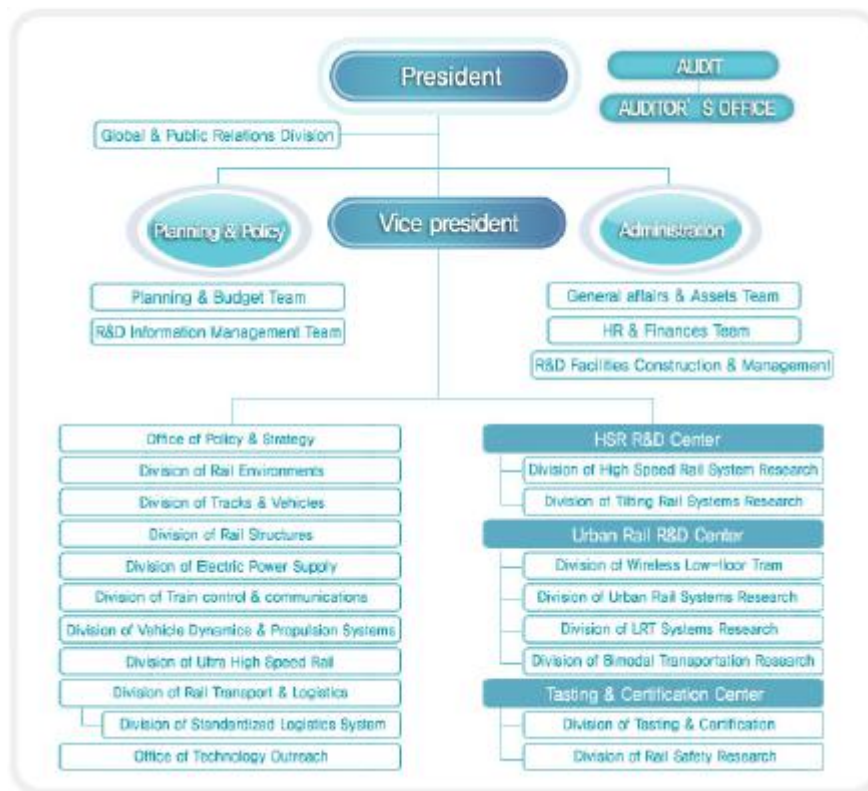


Figure 20. Organizational Chart of KRRI¹¹⁰

In recognition of its own research capacities, KRRI has entered extensive partnerships with foreign governments and universities. For example, after completion of technology transfer from French TGV for original trainsets, KRRI researchers began work on the HSR-350x bogie, which was tested at CARS' test track under an agreement with the Chinese government.¹¹¹ Further, KRRI has recently invested in a research partnership with the University of Sheffield Department of Mechanical Engineering through Rail Research UK, set up office there, and the two parties are working jointly on wheel/rail contact research.¹¹²

Highlights from the European Union for Training Below the Baccalaureate Level

Although European HSR systems exist, and that there is a demonstrated need to train and educate the HSR workforce of these systems, the European Model is complicated by the federated and unique aspects of the system. Thus, examination of the European method of training/education provides us with further insight into possible methods of training/education.

The situation in the European rail industry is that there are state owned rail operators who either deliver their own training or have an exclusive agreement with one training centre to deliver all their training needs... Training is paid by the rail operator. Most training facilities are financed by the rail operator. Only in three instances are rail facilities paid [directly] by government.¹¹³

The European railway sector employs more than 900,000 people, an increasing number of whom are being trained at rail academies or training centers/trade schools. Currently, these centers train an estimated 11,000 train drivers and around 20,000 other rail related staff a year.¹¹⁴ “Nowadays admittance to training includes both psychological and physical assessment, and the training involves knowledge of rules and regulations, safety procedures, knowledge of traction and train handling, as well as knowledge of routes.”¹¹⁵

There are over 100 rail training centers throughout Europe, providing anywhere from highly specified rail operations and maintenance functions (i.e., signaling technology or train driving) to broad-based rail engineering education comparable to an A.A./A.S.-degree level. Slightly fewer than half of these training centers use simulator technology in preparing train drivers, who typically receive the greatest amount of training and take more examinations before being qualified.¹¹⁶ Deutsche Bahn (Germany) is a proponent of utilization of simulators for training and retraining, operating 17 total, including ICE trainsets.¹¹⁷ These training tools typically feature a working replica control panel and can simulate weather and other potentially problematic conditions. Notably, no such simulator is currently operational in the state of California, and this is an example of a key technological shortcoming that may be integral to the state’s training and research needs.

The Vocational Mindset

The European education system differs from that of the United States by encouraging vocational training from the teenage years. Consequently, a greater number of apprenticeship-type programs and technical colleges exist in European economies. Further, generally speaking, a greater emphasis is being placed on preparing future generations to fill the workforce gap created by declining birth rates as well as efforts to place at-risk youth in meaningful employment. German carrier Deutsche Bahn annually conducts the Chance Plus Internship program for 500 young people with poor grades, offering classroom study, practical experience, and counseling services to participants.¹¹⁸ Also indicative of an emphasis on young workforce entrants, many European operators are making a pointed effort to provide internships in tasks such as customer service and electronic systems, such as that featured by ScotRail’s training center in Glasgow.¹¹⁹ The total lack of rail trade school entities in California again speaks to the massive void of training capacity below the college level.

CURRENT STATE OF EDUCATION AND TRAINING IN CALIFORNIA

At present, as in other states, transportation engineering course work in California exists largely as a subdivision of colleges of civil engineering, occasionally falling under structural, mechanical, or building engineering rubrics. Many aspects of such course work relate to urban planning and design while also addressing systems theory, transport operations (trucking and maritime), and maintenance and evaluation of roadways. Transportation engineering concentrations (or specializations) in advanced-degree civil engineering programs are currently offered by California State Polytechnic University, Pomona (Cal Poly Pomona),¹²⁰ California State Polytechnic University, San Luis Obispo (Cal Poly San Luis Obispo),¹²¹ California State University, Long Beach (CSU Long Beach),¹²² Sacramento State University, San José State University (SJSU), and the University of California, Berkeley (UC Berkeley) (see table 18). This list may overstate the state’s current offerings, however, as the only rail-specific element advertised by any such program is “Operations

and Transportation Terminals” at UC Berkeley, which addresses characteristics of rail yard management.¹²³ A perusal of civil engineering degree programs at California State University and the UC Berkeley indicates that Transportation Engineering course work at the undergraduate level usually consists of one or two required courses in transportation planning and traffic flow theory.

Table 18. Existing Advanced Degree Training in Transportation Fields

Degree	Institution
Transportation Management M.S.	SJSU
Global Logistics M.A.	CSULB
Civil Engineering M.S. or M.Eng., PhD	UCB, USC, CSUS, CSULB, CPP, CPSLO, SJSU
Transportation Concentration	
Transportation Science M.S., PhD	UCI
Transportation Technology and Policy M.S., PhD	UCD
Transportation Policy and Planning M.A., PhD	UCLA

Table 19 presents the current offerings in transportation at various UC and CSU institutions. UC Berkeley is the Western Region (DOT Region IX) UTC. The University of California Transportation Center (UCTC) and the Institute of Transportation Studies (ITS) serve as key research entities at UC Berkeley, the former receiving UTC designation and operating under the regional theme of “Transportation Systems Analysis and Policy.”

Currently, the UCTC coordinates research from five UC campuses, collaborating with other departments (e.g., Department of Urban Planning at the University of California, Los Angeles; UCLA) to produce works pertaining to implications of specified laws and practices on fuel efficiency, intersection safety, and other desired policy results. The UCTC also is extensively involved in Intelligent Transportation Systems research, figuring ways to best incorporate rail into various transit environments. ITS is the umbrella institute for transportation research at Berkeley (Branches also are present at UC Davis, UC Irvine, and UCLA), which was established with a mandate to support the needs of the State of California, particularly pertaining to highway construction and maintenance post-World War II.¹²⁴ According to staff at Berkeley ITS, over the past decade, the programs on pavement technology have dropped off, and the ITS is conducting more projects around public transit and environmental impact analysis.

The ITS is now actively building capacity to address HSR issues in response to its mandate to be able to advise the state, but the University of California system does not presently offer any courses in rail transport and does not have the resources to develop one in the near term.¹²⁵ However, as UC Berkeley is consistently among the top civil engineering and transportation engineering programs in the country, it could be involved with a transition to HSR knowledge creation and information dissemination with a number of transportation analysis, methods, and logistics courses that could likely be amended to incorporate rail generally and HSR specifically.

UC Irvine’s Transportation Sciences Program trains master’s and doctoral students in travel demand modeling, traffic analysis, and policy analysis in an interdisciplinary

effort between the University's Civil Engineering, Economics, and Urban and Regional Planning departments. Recent research outputs from this branch of the ITS have focused on intelligent transportation systems, pricing, and travel demand.¹²⁶ Stemming from the UC Irvine's focus on intelligent transportation systems, the publication also includes an overview of transit agency suggestions for integration or expansion of existing public transit, particularly a light-rail extension in Los Angeles to the proposed Norwalk HSR station and the Anaheim Rapid Connection fixed guide way system to the Anaheim Regional Transportation Intermodal Center.

UCLA's ITS is based at the School of Public Affairs. Master's-level Transportation Planning specializations are available through the Departments of Public Policy and Urban Planning, with a PhD being offered in Transportation Policy and Planning through the Urban Planning Department. Course descriptions discuss multimodal planning as well as incorporation of rail in urban form and design, but do not delve into the technological components of track or trainset.¹²⁷ Further, the institute's research focus (in line with a policy analysis regional theme) is on integration of rail in smart land use, and (light) rail finance and security.

UC Davis's ITS likewise takes an interdisciplinary approach in conferring degrees in Transportation Technology and Policy; research foci include sustainability practices, travel behaviors, and environmental impacts and emissions of various modes. Particular attention is paid to hybrid vehicles and other clean energy practices. The ITS Davis has not published any studies pertaining to rail technology, but does have an existing partnership with clean energy researchers at Tonji University in China¹²⁸ that might theoretically be applied to shared HSR emissions and environmental impact research.

California State University, Long Beach offers a master's in Global Logistics, which focuses on integration of transportation modes in goods delivery, supplier relations, inventory, warehousing, and other concepts related to logistics and distribution. The program does not address rail, instead focusing its energies on activities based out of the Port of Long Beach. However, the university conducts transportation research in consort with the University of Southern California (USC) via the Metrans Transportation Center. Research conducted by USC Metrans researchers is largely concerned with safe, efficient movement of goods and people, but some applied research topics are in the areas of infrastructure and security. For example, in 2005, USC led the study "Analysis of Vibrations and Infrastructure Deterioration Caused by High-Speed Rail Transit." Collecting data from Europe, Metrans researchers were able to apply rates of HSR-induced soil displacement in differing environmental conditions,¹²⁹ the theoretical application being to Los Angeles area soil and infrastructure. This is the type of research question that California researchers will field as the system is built out and maintained.

SJSU offers bachelor's and master's concentrations in Transportation Engineering. Most course work at both levels is geared toward highway engineering. In addition, SJSU's College of Business offers a master's in Transportation Management, emphasizing leadership skills, policymaking, and security, and is currently offering a graduate certificate course in HSR management. As noted earlier, the University of California, San Diego has a prominent engineering program, with current FRA projects to do seismic engineering analysis of rail systems.

Table 19. California's University (CSU and UC) Offerings in Transportation

University	Undergraduate Course Work in Transportation Engineering	Master's-Level Course Work in Transportation Engineering	PhD-Level Course Work in Transportation Engineering	Affiliated Research Institutions	UTC Research Theme	Rail Research	HSR Research
UCB	Yes	Yes	Yes	ITS, UCTC, ITE	Systems Analysis and Policy	Yes	Yes
UCD	Yes	Yes	No	ITS, Air Quality Research	Sustainability	No	No
UCI	Yes	Yes	Yes	ITS	N/A	Yes	Yes
CSULB	Yes		No	Mettrans, CITT	Metropolitan		
USC	Yes	Yes	Yes	Mettrans	Metropolitan	Yes	Yes
SJSU	Yes	Yes	No	MTI	Systems Policy and Management	Yes	Yes
CSUSB					Decision-Making and Management of Systems		

California's training and research capacity is bound by a number of factors, with existing funding incentives and research themes being paramount. While scattered efforts at applied HSR research have been conducted (e.g., the Metrans study), California collectively does not possess the capacity or thematic direction to conduct basic or applied research in areas pertaining to HSR infrastructure development, operations, and maintenance. It probably also is poorly positioned to create new doctorates with the background to help produce new cohorts with bachelor's and master's degrees with technological expertise in areas relevant to HSR.

As documented earlier, the CHSR project may require as many as 6,300 engineering PY. Aggregated, the CSU and UC systems produce comparable numbers of engineering graduates annually (see table 20) and may be able to address the needs as shown in the projected demand.

Table 20. Engineering Degrees from the UC and CSU Systems, Annually (2007–2009)**2008–2009 Engineering Degrees Conferred**

	CSU System	UC System	Total
Engineering Bachelor's	3,857	3,080	6,937
Engineering Advanced Degrees	1,434	1,235 (master's) 689 (doctoral)	3,358
Total	5,291	5,004	10,295

2007–2008 Engineering Degrees Conferred

	CSU System	UC System	Total
Engineering Bachelor's	3,908	2,980	6,888
Engineering Advanced Degrees	1,286	1,209 714	3,209
Total	5,194 ¹³¹	4,903 ¹³²	10,097

Recognizing that a substantial number of engineers are graduating from California's institutions, one direct answer to university training appears to be augmenting existing degree programs, particularly Transportation Engineering concentrations, to include rail-specific courses and specializations or majors.

We have earlier identified at least 4,273 PY to be filled by bachelor-level trained construction field management who will be responsible for translating HSR technical specifications to line personnel, and to assure quality control compliance as mandated in technical memorandum. To do so effectively, these workers will require a firm basis and systematic understanding of HSR knowledge and information and technology components to also facilitate the communication of concerns between engineers and construction workers in troubleshooting of the build-out.

Essential university-level training for these workers will likely take the form of interdisciplinary construction management and transportation engineering programming, modified to include elements of rail management. Recognizing that this project will probably not create enough immediate demand for every engineering and construction management department to rush to modify their curricula, the following CSU programs have been identified as areas of acclaimed programming in both areas to possibly spearhead university response to this need:

- CSU Long Beach
- Cal Poly Pomona
- Cal Poly San Luis Obispo

Recognizing that CSU Long Beach (in partnership with USC) is the Tier I UTC in Southern California, if the CSU is to actively engage in HSR education and research, CSU Long Beach will logically present a nexus point. Meanwhile, Cal Poly Pomona has begun implementing rail engineering course work and is establishing a student exchange partnership with Chinese entities, at the North China University of Science and Technology,

Beijing, in disciplines of Social Sciences, Science, Engineering, Math, Language Study, and Computer Science.¹³³

POSSIBLE MEANS OF ACHIEVING WORKFORCE GOALS

Paramount to the success of the process of California universities spearheading research efforts is a concise division of research and system of communications. One early example of how the latter may function is the REES model of online drop boxes and interfacing, described earlier in this section.

However, to prevent the online consolidation from becoming a disorganized hodgepodge, a firmer structure of HSR-specific research themes needs to be agreed to by various participating CHSR centers. Within this structure, recognition of the Northern California/Southern California geographic divide may be necessary. Each has its own fault lines, soil densities, and other physical concerns that may not be applicable across the system. Whether this is delineated via a conference or other means is to be determined, as California professors able to perform basic and applied research at various levels on the Technology Readiness Level scale have yet to identify areas of interest in any organized forum. The incentive to organize has not previously been present for a number of key reasons such as federal expenditures for Volpe Center activities and the lack of test-track and other test facilities in California.

As the Central Valley section of the build will be an incremental upgrade, initial learning will take place during this process. New technology will be developed by this group of to-be-determined individuals. They then will be pivotal to knowledge creation in partnership with graduate students and information dissemination in the classroom.

THE FUTURE OF HSR EDUCATION AND TRAINING IN CALIFORNIA

The following are a series of general strategies California may wish to study further to develop the urgently needed capacity for further training, education, and applicable HSR research. These options are neither exhaustive nor mutually exclusive, and the best direction moving forward may entail a combination of many of them.

Ways to Increase the Capacity of HSR Training and Related Higher Education

- A key finding of this report is that the preponderance of the positions created directly by HSR development will require relatively little in the way of higher education, but much in the area of HSR-related training. Apprenticeship programs sponsored by labor unions and others will almost certainly play a major role, but their capacity must be vastly enhanced and increased for this to be realized.
- Similarly, community colleges will need to play a significant role by offering courses and possibly certificate programs or two-year specializations in the many areas of HSR construction and management detailed earlier in this report. The community college system currently offers almost nothing in this regard, but it is an adaptable and flexible system that—given appropriate direction and funding—can step up its contributions in a relatively timely way.

- With respect to the many positions that will require baccalaureate or advanced degrees, there is a clear need to expand existing civil engineering degree programs with concentrations or specializations in transportation engineering to include railway engineering (and HSR-specific) course work specifically. This would best be applied to universities with existing concentrations in transportation engineering and existing individual courses in design, modeling, surveying, inspection, and regulations, whose offerings may be more readily augmented to include greater emphasis on rail generally and HSR specifications particularly.

A small number of American university professors are building relationships with researchers in HSR-equipped nations. The time has come for professors in California to establish relations with such contacts abroad. Some capacity for this collaboration already exists in the AREMA committees, the TRB cooperative, and the UTC structure described earlier.

- Reform current research themes and the greater RITA funding process within UTCs in California and beyond. Very little capacity exists for basic research, much less applied research, pertaining to HSR at these institutions. Achieving these reforms may result from (a) realignment of research themes in Region IX to include HSR technological advancements and specifications; (b) designating universities as HSR centers; entailing direct faculty and advanced degree candidate interaction with foreign training entities to be disseminated to students of these programs. However, this implies a higher degree of collaboration between and within existing university programs in civil engineering (transportation engineering), transportation management, and institutions.

Such an effort also might include a shift to a process wherein the FRA proposes engineering questions directly to researchers at these institutions, improving communications mechanisms from the current process of open-ended RFPs disseminated by FRA/research guided by TRB panels. More generally, some national-level institutional response is needed to sponsor and coordinate research and development of HSR-related information, knowledge, and technology in a manner analogous to such centers in other nations.

In sum, for the California (and national) HSR system to be competitive and sustainable, it will need to be constructed, operated, maintained, and improved by a knowledgeable workforce. For there to be an adequate number of specially trained engineers, construction managers, and other key personnel by the project's peak year, California universities need to play a lead role in that effort; CSU and the UC must begin aligning their efforts now. However, the bulk of the projected workforce will not require college degrees; it will require HSR-specific training and certificates. The community college system, along with the trade apprenticeship programs, needs to be provided with a clear indication that HSR-related education and training are urgently required—and appropriately funded to shift capacity in that direction. The sooner such efforts are begun, the greater the likelihood of the timely and successful creation of a safe and efficient HSR system.

APPENDIX A: DATA AND METHODS

This appendix describes in depth the methods used to estimate and measure the workforce needed to complete the system, within the project delivery sequence, specifying the demand for the CHSR workforce in as detailed a fashion as currently and accurately as possible. It connects the quantitative assessment to qualitative personnel estimations directly to demonstrate workforce and education needs. The CHSRA has released estimates of the requirements for the workforce that would be necessary to build-out and operate the CHSR network. In this section, we discuss the prevailing method used to estimate HSR workforce needs, and contrast it with those used in this project. By quantifying demand in the more data-rich and detailed method discussed in this section, we are able to gain further insight into the general workforce needs outlined in Section I.

OVERVIEW OF THE CHSR PROJECT DELIVERY METHOD

To understand the demand that is created by the construction of the CHSR network, we must introduce how the project delivery sequence influences the number and type of professionals/personnel needed over the life of the project. The entire process is predicated upon the project delivery sequence, including the following four general categories, Design, Build, Operations, and Maintenance (DBOM).

DBOM

The CHSR network will be completed in the DBOM sequence. (Note that in this context, the sequence prescribes a series of actions that need to take place, and not a procurement method.) The assumptions that inform our estimates for workforce development will be structured around this general project delivery sequence, which is representative of how most projects are accomplished temporally. For our purposes, creating a distinction among the different personnel associated with each separate grouping allows us to more easily create estimates and other data pertaining to workforce demands, based on detailed constraints that we apply.

The DBOM sequence is a method associated with industry-accepted standards regarding contracts that are created to deliver construction projects. It is used by an agency or owner for organizing and financing design, construction (build), operations, and maintenance services for a structure or facility.¹³⁴ This is done through entry into legal agreements with one or more entities or parties in a process by which a construction project is comprehensively designed and constructed for an owner, including project scope definition; organization of designers, constructors, and various consultants; sequencing of design and construction operations; execution of design and construction; and closeout and start-up. Given gradual changes in procurement laws, public agencies now share the ability of their private sector counterparts to acquire construction services via alternative project delivery methods, such as construction management, design-build, and other hybrid systems. In some instances, some of these methods (e.g., design-build) may include operations and maintenance as well as multi-year warranties in the contract. The engineering system's integrator is engaged in the optimization of the project delivery and finance configuration at both project and system levels.¹³⁵ This is recognized by the CHSRA and the CHSR Program Management Team, which have outlined various procurement methodologies generally. The Authority is currently considering a wide variety of project delivery approaches to

optimize the allocation of risks. These approaches can include a range of private and public participation levels.

Project Delivery Method and the Impacts of the Procurement Selection Process

Although we identify patterns of the project delivery cycle, there are factors that impact the estimation of personnel, in the delivery method as discussed earlier. The major influencing factor is the method of procurement, which is currently being assembled by the Program Management Team. The choice of procurement methods is likely to have an impact on the discussed sequence of delivery (and indirectly, change the personnel/professional measurements accordingly), and one of the important aspects of the HSR build-out that remains undefined at this date is how the project will be allocated to stakeholders and participants. Such decisions are likely to have an impact on the estimates developed for this report. At this time, the subtleties of this factor and its impact on the potential labor force cannot be quantified for this report. Thus, we in effect hold these elements constant, in recognition that the Authority is engaging in analysis to implement the most effective bid type, and that there is existing research concerning the factors associated with the different contract bid types. Instead, we draw patterns from the existing cost structure, project delivery periods, and other factors as a means through which to accurately depict a large sample of the workforce needed, with as much detail accomplishable, to complete the representation of the CHSR network project delivery process.

The Goal of Measuring Workforce

Recognizing how the procurement method has the potential to impact our estimates of workforce needed, we accept the project delivery method of the DBOM sequences as being an acceptable method of measuring the workforce, specifically isolating and measuring each of those affiliated phase personnel/professionals, for our project. Specifically, we estimate the overall workforce required to construct the CHSR network by examining the professionals and trades persons affiliated with the activities within that sequence, with appropriate assumptions applied to observe the affiliated workers within that particular sequence.

Design Sequence

The design phase is comprised almost exclusively of professionals who hold advanced degrees and are specialists affiliated with the development, evaluation, and implementation of design schematics and drawings in engineering, managerial engineering, and related professions. They will be challenged with design and development of the complex technological HSR systems. The team is often comprised of professionals such as surveyors, civil engineers, cost engineers, mechanical engineers, electrical engineers, structural engineers, and fire protection engineers. These professionals most often hold engineering and specialized degrees. This holds true in the CHSR project's design demographic as well, which confirms the intense involvement of engineering professionals (for the purpose of preparation of technical memorandum and schematics) as well as teams of specialists who are designated to accomplish specific specialist tasks (e.g., the compilation of NEPA/CEQA, and EIR/EIS compliance documentation).

The design process involves many major engineering activities that require unique skills. One such skill is the exploration of possibilities and constraints by focusing critical thinking skills to research and define a problem. (In the case of HSR, this conceptualization is critical.) A second component to this is redefining specifications of design solutions that can lead to better guidelines for traditional design activities (better understood as systems that are designed with costs, labor, time, and other elements as central elements of the design process). A third integral process involves prototyping possible scenarios, or solutions that incrementally or significantly improve the inherited situation. (For the CHSR model, the need to adapt to political and other emerging climates that impact the build strengthens the design capacity of the Design Team for the project.) The critical element here is that the team possesses the professional skills to adjust existing engineering models to emerging and real-time complexities in the HSR project. As a result, this smaller, but elite, team of professionals will continue to play key roles as the designers of highly complex HSR systems.

Overall, the design phase of the project is a period of preparation for the procurement process, when either adopting previously deployed design methodologies and/or modifying design techniques occurs. Thus, a dynamic design team allows for both flexibility to adapt to a changing task environment and rigidity to deploy the necessary engineering and architectural framework for complex projects such as the CHSR build-out. In addition, the team must be ready to troubleshoot problems that arise as the project goes to the field, which is scheduled currently in the 2012 period.

Funding and Patterns Similar to our DBOM Cycle

A similar project delivery cycle was manifest in the funding of higher speed passenger rail (Acela) in the Northeast Corridor over a period of 20 years. After enactment of the Railroad Revitalization and Regulatory Reform Act of 1976 (the 4R Act) by Congress, Amtrak became the primary owner of the railroad rights-of-way in the Northeast Corridor. The funding stream used to complete corridor upgrade can be represented as a wave cycle that was distributed over a period of 20 years, with heavy investment in the initial seven years. Figure 21 provides a visual comparison between the funding patterns for the Acela project (1978–1996) and that planned for the CHSR system (2009–2029).

For Acela, this period was labor-intensive, requiring more funding for upgrade purposes, purchasing the land associated with the Northeast Corridor development, and to refurbish/restructure. This funding declined in the 1987 period, but again increased (presumably for maintenance) in the 1993 period. Direct comparison can be made between build-oriented activities in the corridor (1978–1996) and the project delivery cycle we have outlined. Both exhibit similar funding and cost patterns that mirror the project delivery sequence.

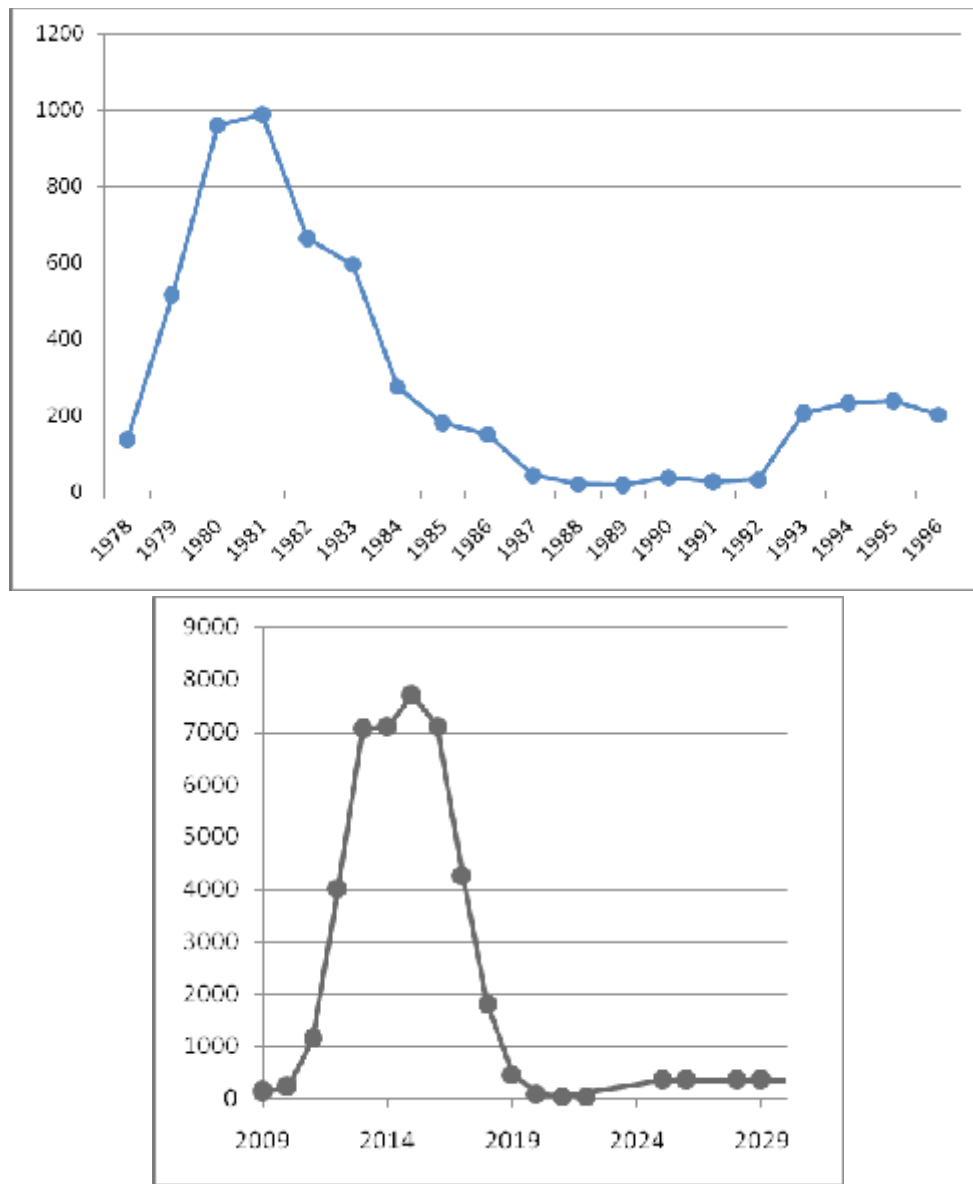


Figure 21. Comparing Appropriations for Northeast Corridor Fiscal Years 1976–1995,¹³⁶ in Real 1995 Dollars (left), and CHSRA 2008–2029 (right), from CHSRA Report to Legislature

EXISTING PERSONNEL MEASUREMENTS OF INFRASTRUCTURE PROJECTS

The Prevailing “Top-down” Methodology

What we refer to as “top-down” methodology is the standard way policy analysts and researchers assess personnel ratios in large infrastructure projects, to provide estimates of the total workforce created in a large project. To date, transportation workforce analyses and research primarily has often relied upon a widely accepted, yet somewhat crude, measure of a given ratio of jobs created per \$1 billion of infrastructure spending. Such estimates are often derived from another type of modeling, known as IMPLAN Input-Output

modeling, in which cost estimation is applied to measure estimates of total personnel, where cost and spending employ specific types of personnel/professionals (i.e., where total labor need is a combination of direct labor, indirect labor, and induced labor). IMPLAN modeling is a more complex modeling technique that has been modified for use in the top-down methodology by policy analysts and researchers; however, it is still a relatively crude process of measuring specific impacts.

The job projections of the San Francisco/Silicon Valley Corridor Investment Strategy¹³⁷ applied such a measure as a means to quantify the amount of labor needed to complete the San Francisco to San José portion of the HSR network; using a measure of 25,000–30,000 per \$1 billion as the method of measuring the estimated workforce. The use of this industry norm to project jobs impacts of construction projects also was used in a recent UC Irvine study associated with the construction of the Anaheim Regional Intermodal Transportation Center, in which the metric of 20,000 jobs per billion was used.¹³⁸ This study uses the same approach to assess the number of construction employees who will be working on the design/build phase of the facility, and sought to quantify the workforce, in accordance with the Authority's projected job-to-expenditure ratio. It applied the CSHRA reported average of 3.75 years per construction job, and provides a preliminary estimate of the total jobs created in accordance with patterns that are consistent with the assumption that workers will be employed for more than one year and infers that there is potential for construction workers to be employed on different portions of the segments to be built. Although it employs acceptable ratios and interpretation of the expenditure ratios, this approach does not enable the measurement of specific jobs and their skills, and is essentially a very rough estimate of the anticipated workforce needed for this specific project.

Other research that estimates production of jobs from construction projects has relied upon similar jobs-to-expenditure ratio projections. In a recent report from the United States Conference of Mayors, the jobs-to-expenditure metric is used with respect to anticipated increases in city gross regional product, in at least a portion of the measurement methods.¹³⁹

The American Public Transportation Association (APTA) uses a very similar measure, based on more complex IMPLAN modeling and adjusted for more top-down measuring.¹⁴⁰ The rate for federal funding of public transportation reflects a specific mix of capital investment and preventive maintenance funding as allowable by law. APTA suggested that under current federal law, an estimated 30,000 jobs are supported per \$1 billion of spending.¹⁴¹ The national rate can vary from 24,000 to 41,000 jobs per \$1 billion of spending, depending on the spending mix. The lower figure holds for spending on capital investments (vehicles and facilities) while the higher figure holds for spending also on transit system operations.¹⁴² Across the entire \$47 billion spent on public transportation in the United States each year, an average rate of approximately 36,000 jobs per \$1 billion of public transportation spending has been calculated. This figure is based on the national mix of public transportation spending as of 2007, including a direct effect of spending in transportation-related manufacturing, construction and operations as well as orders to suppliers or by re-spending of worker income on consumer purchases.

The CSHRA has applied a figure of 20,000–21,000 jobs per \$1 billion of spending, stating that its estimates were intended to be conservative and prudent.¹⁴³ At the time of the projection, the project was estimated to cost \$30 to \$35 billion, resulting in a projection of 600,000–650,000 created jobs. This figure, however, includes all employment projected

to be associated with the completion of the project, including jobs not directly required to create and operate the system.

Rachel Wall of the CHSRA stated: “We are using the calculation of 20,000 jobs per \$1 billion of infrastructure funding, which is less than the estimate by the federal government and comparable to that of many other transportation agencies and projects. The Authority is being conservative in its estimate of 600,000 construction-related jobs from the construction of Phase 1 of the project. A \$42.6 billion project using that calculation could actually produce more than 850,000 jobs, but the lesser figure of 600,000 allows for inflation and other factors.” Therefore, the CHSRA has applied the standardized and conservative metric that depicts the total employment created over the life of the California high-speed rail construction.

We further see acceptance and use of this approach at state and federal levels. For many years, the Federal Highway Administration (FHWA) has periodically estimated the employment impacts of highway capital expenditures. For 2007, on average, the FHWA estimated that \$1 billion of federal highway expenditure supported 30,000 jobs. In the case of related costs to right-of-way acquisition, in this case 7 percent of costs, the associated jobs per \$1 billion is estimated at 27,800. This is not far from the APTA estimate of 24,000–41,000 jobs.

In comparison to the CHSRA jobs-to-expenditure ratio projections, current Phase 1 costs in the 2009 Business Plan (BP) confirm that current right-of-way estimates are anticipated to be comparable to 7 percent of the cost. (Right-of-way for the CHSR project is expected to be \$2.892 billion of the overall \$39.283 billion project, according to Phase 1 projections.) Right-of-way acquisition costs may have been a contributing factor to lower the Authority’s jobs-to-expenditure ratio. Overall, the FHWA estimates of 27,800 jobs created per \$1 billion is comparable to the Authority’s 20,000, which remains conservative.

Further, the American Association of State Highway and Transportation Officials (AASHTO) uses a similar measurement of jobs created per \$1 billion in spending: a ratio of 24,000 jobs per \$1 billion capital investment as the accepted employment impact on construction and manufacturing jobs.¹⁴⁴

Overall, under current federal law, an estimated 30,000 jobs are supported per \$1 billion of spending. The highest jobs-per-billion ratio identified is 41,000 per \$1 billion of spending. The national rate can vary from 24,000 to 41,000 jobs per \$1 billion of spending, depending on the spending mix. The lower figure holds for spending on capital investments such as vehicles and facilities while the higher figure holds for spending on transit system operations and is accepted as the number of operation and maintenance jobs per \$1 billion operating investment.¹⁴⁵

Construction (Design and Build) Workforce Estimates Methodology by the CHSRA

Details of the costs associated with the construction (design and build) component of the build have been released, and are annually updated in the CHSRA BP documents.¹⁴⁶ The latest draft describes the 2012 Business Plan and was released in November 2011. These measurements are prepared and updated annually by *Parsons Brinckerhoff*, the firm responsible for CHSR Program Management Team. The CHSRA BP documents provide

aggregate statewide cost estimates. The overall total construction cost estimate describes the projected build costs for each of the cost elements between 2009 and 2020. As stated earlier, to establish an estimate of personnel related to the cost estimates discussed earlier, the CHSRA has applied an accepted industry measure similar to those discussed earlier in estimating the construction workforce for the design and build phases of the project. Its estimates of workforce are highlighted next.

The CHSRA has estimated that building the CHSR network will directly result in the creation of 160,000 construction-related jobs. Construction of the project also will result in an additional 450,000 indirect or induced new permanent jobs by 2035. The Authority has expanded on this, by releasing estimates of workforce associated with regional project alignment: “The high-speed train system will generate 600,000 jobs over the life of construction (one-year, full-time equivalents over approximately eight years).¹⁴⁷ This further has been broken into estimates, by corridor, according to the 2009 BP; moreover, the measurements are currently being adjusted related to the November cost projection:

Table 21. Segment and Personnel Employed, CHSRA

Segment	Personnel Employed
San Francisco to San José	105,000
San José to Merced	112,000
Merced to Bakersfield	135,000
Bakersfield to Palmdale	81,000
Palmdale to Los Angeles	125,000
Los Angeles to Anaheim	92,000

While the calculation is a bit more complex, a simplified and conservative version has estimated the combined total of directly and indirectly related jobs for an infrastructure project of this sort at approximately 20,000 generated per \$1 billion of construction, based on the 2009 BP projection.¹⁴⁸

Essentially, the CHSRA has implemented a top-down measurement to arrive at the projected workforce necessary to complete the CHSR network. This measure subsumes direct, indirect, and induced projected workforce elements, and is consistent with the estimating metrics established in the literature mentioned earlier. One reference noted that each job directly created in the chain of manufacturing activity generates, on average, another two and one half jobs in such unrelated endeavors as operating restaurants, grocery stores, barber shops, filling stations, and banks, thus accounting for many of the “induced” jobs.¹⁴⁹ Overall, multiple tiers of employment are recognized as parts of total number of personnel needed to construct the system (e.g., direct on-the-ground employment, indirect supply chain employment, and induced re-spending and support services employment).

Given the widespread adoption and industry use of the top-down job creation measures, the ratio of 20,000–21,000 professionals per \$1 billion in spending that has been used by the Authority is an acceptably conservative ratio. The next step is to examine these measurements in terms of their smaller components, which consist of direct, indirect, and induced job measurements. Table 22 provides a breakdown of these job categories,

distinguishing categories of direct effects (public transportation manufacturing/construction and operations jobs), indirect effects (jobs at suppliers of parts and services), and induced jobs (jobs supported by workers re-spending their wages). The column on the far-right provides a blended average.

Table 22. APTA Jobs (PY) per \$1 billion, Economic Development Research Group Modeling

Jobs per \$1 billion	Capital	Operations	Blended Average
Direct Effect	8,202	21,227	17,450
Indirect Effect	7,875	2,934	4,367
Induced Effect	7,711	16,979	14,291
Total Jobs	23,788	41,140	36,108

As shown by the Economic Development Research Group data from that APTA report (*Job Impacts of Spending on Public Transportation*), there is a sliding scale related to how to interpret direct, indirect, and induced labor. The Group explicitly discussed the validity of using a sliding scale in their report.¹⁵⁰ It is significant to take the aforementioned personnel estimates of direct, indirect, and induced job growth and convert them into a ratio that shows differences in the capital, operations, and blended average ratios. The outcomes are shown in table 23.

Table 23. APTA Jobs Per \$1 billion, Economic Development Research Group Modeling, as a Percentage, Showing Differences in Capital, Operations, and Blended Average Ratios

Jobs per \$1 billion	Capital	Operations	Blended Average
Direct Effect	0.34480	0.5160	0.4833
Indirect Effect	0.33105	0.0713	0.1209
Induced Effect	0.32416	0.4127	0.3958
Total Jobs	1.00000	1.0000	1.0000

Here, we define each type of spending:

“Direct” spending, according to the APTA report, can include spending on “capital investments” such as building or constructing buses, trains, stations, tracks, maintenance facilities, equipment, and so on. It also can include spending on ongoing operations of public transportation systems—including bus and train operations, maintenance activities, and administration. In the APTA model, direct effects account for a blended average of 48 percent of the total jobs created, according to the spending of \$1 billion, but also can account for only 34 percent of the total jobs created, when more capital-focused activities are conducted. The DOT frames direct jobs as those represented by the number of people whose work is directly billed to the project.

Spending also has “indirect effects” on employment in supporting industries (i.e., those that supply goods and services to enable the direct spending, including workers in industries

supplying engines, equipment, and the steel, concrete, wood, and plastic materials that are needed for building vehicles, guide ways, and station facilities). Indirect jobs account for an estimated 12 to 33 percent of total jobs created, in accordance with expenditures of \$1 billion. The DOT frames indirect jobs as those representing employees working for producers of materials, equipment, and services that are used on the project, such as steel producers and producers of accounting services.

Finally, direct spending also has the impact of creating jobs through “induced” effects of the re-spending of worker income on consumer goods and services such as food, clothing, shelter, recreation, and personal services. These jobs account for 32 to 39.5 percent of the total jobs that are projected to be created, per \$1 billion spent, depending on the intensity of the capital expenditure process.

In summary, there are three levels to the job projections that represent acceptable ratios of personnel-to-expenditure ratios. The workforce on all projects is thus a combination of the direct, indirect, and induced workforce needed at the same time, as three different tiers involved in an infrastructure delivery process. For our purposes, however, only the direct workforce is of immediate interest, as representative of persons who will require HSR-related education and training over the life of the project.

The Scope of Estimates in this Report

This report will focus only on jobs created by the direct spending on the HSR project. It will omit any estimation or analysis of jobs created by indirect and induced effects of building the CHSR because we lack sufficient data upon which to estimate the specific kinds of positions indirect (e.g., supply chain jobs) and induced (spending- and re-spending-created jobs) that will be created as well as the kinds of education and training that they will entail. We do not dispute the existence of the other workforce elements, but they are beyond the scope of this project. Therefore, although we will make occasional mention of the larger total of jobs forecast to be created by the project, our methods will focus on identifying and analyzing the jobs directly involved in the DBOM of the CHSR project, and suggest that equally complex modeling be constructed to examine the CHSR indirect and induced workforce, based on our findings.

The top-down estimation method, although accurate in identifying total personnel needs and their economic “ripple” effects, has limitations related to accurate estimates of the types of workers who will be utilized during the project delivery process. Further, such do not offer any significant insight into the project-specific workforce personnel affiliated with the build of the CHSR network, and specifically their workforce development attributes. We therefore seek—whenever possible—to expand on the top-down measurements through applying a “bottom-up” estimation technique that will both validate the ratio of expenditure-to-employment figures and—more importantly—provide estimates of specific job types that will be a part of the construction process of the HSR system, within specified and acceptable “benchmarked” ratios. The next section describes the means of measuring these professionals, which includes estimates derived from the bottom up, which affords unprecedented insight into the types of professionals and personnel needed to construct a mega-project such as the CHSR network.

Summary

This section has discussed in detail the data-driven estimation methods that are frequently used to estimate the direct workforce personnel affiliated with the build-out of the CHSR network. This measurement methodology is used readily throughout transportation research, and is derived from a more complex IMPLAN modeling. We have highlighted that the top-down estimation process identifies three levels of personnel affiliated with project delivery (direct, indirect, and induced workforce); however, our approach is to improve upon the existing approach while focusing only on the direct component of the HSR workforce.

MEASURING THE CHSR WORKFORCE

Here, we discuss in detail the methodology used to measure the direct employment needed to construct the CHSR network. This serves as a forecast of demand, for specific professionals and personnel, over the life of the project (2009–2020, with an optional extension into the 2020–2025 operations and maintenance period), and we anticipate patterns that re-create the demand “wave” as illustrated and discussed in Section I. This measurement methodology is separated into three different parts that are primarily, but not exclusively, reflective of the DBOM project delivery sequence:

1. **Design phase methods and estimates:** These include a portion of the Program Management and Construction Management Teams. They are based on basic cost to personnel ratio estimates (i.e., top-down estimates), connected to industry-provided personnel/professional needs of projected variable labor costs, and comply with the DOT estimation of direct personnel, through identifying the number of jobs that represent the number of people whose work is directly billed to the project.
2. **Build phase methods and estimates:** These are further subdivided to include both build management and build construction: (a) The Build Management Team is measured similarly to the design phase method teams, and (b) the build construction methods are based on the much more complex, bottom-up estimation process. This method measures the personnel labor needed to deliver massive tasks and activities associated with the construction of the CHSR infrastructure, on a per-mile and per-element basis. This aspect of the estimation yields the most accurate and detailed estimates, and is described in further detail in the following section, with additional details in Appendix B.
3. **Operations and maintenance phase methods and estimates:** These are based on basic data from the CHSRA and are generally validated with comparative data from foreign firms. We compare three measurements of this workforce, and provide insight into the annual estimated composition of the operations and maintenance staff, post-2019.

Before discussing each method of measurement for the four phases, we introduce 13 data elements that we have used to estimate the labor ratios as accurately as possible. Here, we have the abbreviated section of the data used.

Elements of Measuring the CHSR Workforce

To conduct the bottom-up estimate, extensive and varied types of information were needed for complex analysis of the four phases. To construct estimates of the personnel/professionals needed over the life of the project, each phase was explored using separate and unique methods of measurement, with common overlap connected to the type of personnel needed, the time needed, and other factors. Next, we discuss the various data that were used to create detailed workforce measurements. We look at the primary units that the data provided.

Table 24. Summary of Data Used to Measure the CHSR Workforce

Data Type	Descriptive Information (Composition of Workforce)	By Cost	By Mile	By Corridor	Quantity of Labor	Over Life of Project (Time)
1. CHSR Network Cost Estimation		X	X	X	X	X
2. Technical Memorandum Provided by CHSRA, Program Management	X		X	X	X	X
3. Program Management Team Size/ Type Measurements	X				X	X
4. Rolling Stock Personnel/ Professional Estimates	X				X	X
5. Rolling Stock Build Time Frame						X
6. Variable-Cost Personnel Estimates	X	X			X	
7. Independent GIS Estimation of the CHSRA Network, Phase 1	X	X	X	X		
8. Unit Price Details	X	X	X	X	X	
9. Crew Report, Unit Price Elements	X	X			X	X
10. Tunnel Cost Estimation	X	X	X			X
11. Labor Composition Data	X					
12. Operations and Maintenance Projections	X		X		X	
13. Foreign Operations and Maintenance Projections	X		X		X	

Finding Equal Units of Measurement

After assembling the 13 types of information as shown in table 24, we had to identify a common link between each to construct a complex CHSR workforce model. This was done by identifying the connection between the 13 assembled data elements, and how each was connected to cost, time, labor (over time), labor composition, total needs of systems construction, and so on. Further, each type of information was explored to identify how it

could be adjusted proportionately to measure out the CHSR network, in a representative model. In this process of identifying how each of the elements interacts, we were able to construct a complex HSR workforce labor index based on how each of the phases was constrained by the aforementioned factors. We employ three major methods of measuring the workforce: (a) The design phase and construction management phase are measured in a similar manner; (b) the build construction phase is measured using an ultra-complex, bottom-up method; and (c) the operations and maintenance phase is measured using comparative statistics. We discuss each methodology next.

DESIGN PHASE METHODS AND ESTIMATES

Management for the CHSR project is divided into two main groups: overall, or “program,” management and actual on-the-ground construction management. The efforts of the former begin during the design phase and continue throughout the project; the efforts of the latter begin approximately when the project breaks ground in September 2012 and continue until a given construction phase of the project is built out. Generally speaking, we construct a model that accounts for the fact that the design phase team is planned to be proportionately smaller than the construction management phase personnel. We use the following elements to constrain our estimation of the professionals/personnel, as highlighted earlier in table 24: (a) CHSR Network cost estimation, (b) technical memorandum provided by the CHSRA Program Management Team, (c) Program Management Team size/type measurements, and (d) variable-cost personnel estimates. Using these elements, we construct an estimate of the design phase professionals/personnel.

The basic method for estimating the number of these managers is to make inferences from the management costs built into the plans for the project based on these elements discussed because we do not have information that allows us to internally gauge the entire pay and cost structures associated with the program management and because the construction management phase has not yet begun. We can begin to develop insight into management team composition, through estimating the personnel wages and making acceptable deductions and adjustments, and arrive at a number of personnel that is feasible within the cost structure outlined that represents the design phase and construction management phase professional/personnel compositions.

Program Management (2009–2020)

Table 25 demonstrates the allocated cost structure for the Program Management Team, and shows that this team will work for the entire project, until 2020 (and potentially beyond). When the cost structure of program management is presented in graph form over the life of the project, the potential employment cycle emerges. The key feature of the cost cycle is that there is a natural peak of need for these personnel around 2016—about the time when project construction is at its peak—followed by a phase-out cycle of these personnel. Thus, we anticipate a high point of professional need in the 2016 period, and expect some level of phase out in the 2020 period. If we were to apply the top-down estimation method, we would arrive at approximately 22,324 to 23,443 PY for the project implementation sequence.

Instead, however, we construct a bottom-up estimate to identify specific types of professional services during the project implementation. Although the overall cost reflected in table 25 is not exclusively wages, and it encompasses other cost elements held constant for the

purpose of estimating management needs, the basic method of increasing and decreasing personnel proportionate to the cost cycle holds. Recognizing that there is a set group working throughout the program management process, application of mathematical constraints allows for an accurate estimate of how the program management will expand and contract over the life of the project based on cost, with all other things being equal.

Table 25. Program Management Project Implementation Costs (in millions): San Francisco to Anaheim

Item	'09	'10	'11	'12	'13	'14	'15	'16	'17	'18	'19	'20	TOTAL
PE/Environmental	102	175	290	150									717
Program Management	29	49	61	95	152	158	163	169	112	77	53	28	1,146
Construction Management			116	144	149	193	200	165	242	74	31		1,314
Agency Cost	3	4	6	8	11	19	20	21	21	20	19	20	172
Total, CHSR project	134	228	473	397	312	370	383	355	375	171	103	48	3,349

Figure 22 is a graphical representation of this cost structure as a labor flow, as presented in table 25. The program management cost structure, as per the Phase 1 cost structure, will have a cost/labor cycle, with 2016 (\$169 million) as the high point of cost/labor needs affiliated with this particular design phase group. For program management, there will be heavy cost demand in the 2013–2016 period.

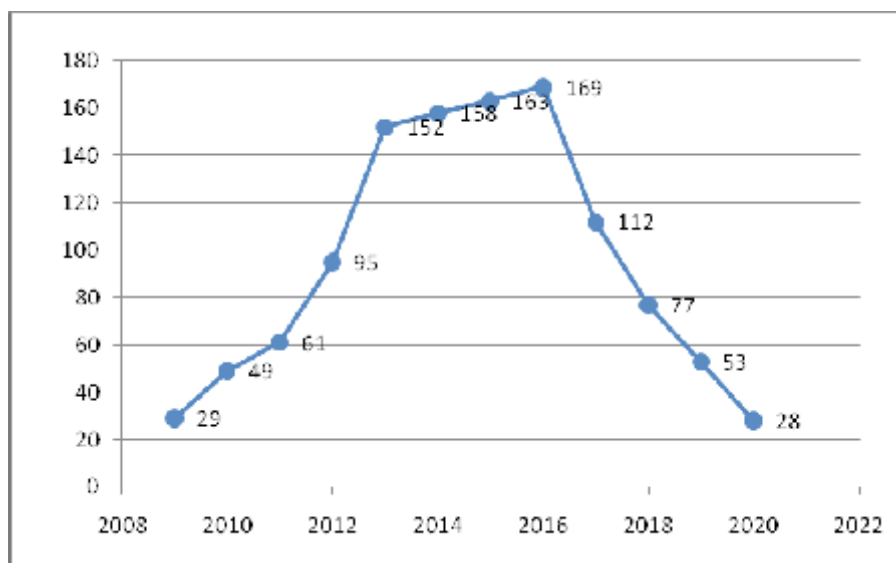


Figure 22. CHSR Network Program Management Cost (in millions), 2009–2020

Setting a constraint on personnel, these data essentially constrain the amount of purchasing capability over the 2009–2020 period for program management, from the bottom-up perspective. The next step is to create a valid measurement of the cost-per-personnel who

will be affiliated with the Program Management Team. To do this, we conduct a basic cost analysis. Merging U.S. Department of Labor's Employment and Training Administration O*Net wage data enables estimation of the wage of the 131 professionals associated with the Program Management Team, resulting in an estimated average annual wage of \$105,178 for personnel associated with this team, absent of seniority and other weighted factors that naturally impact wage. With this estimator, we are able to link the costs of these employees to the anticipated costs within the project implementation period, as shown earlier. We arrive at an estimated number of professionals who can be incorporated into the project according to the estimates outlined in the cost chart. We also recognize that both the design and construction management phases require fewer purchases of equipment and capital, and thus primarily consist of the purchase of professionals and services. As a result, the estimated cost of personnel is heavily reflective on the purchase of professional services, under general adjustments needed to depict the actual purchasing capacity.

This estimate also assumes a range of 0 to 15 percent expenditure (generally, applying an average of 7 percent), reflective of management overhead taken and/or other administrative processes, in acknowledgment that not all allocated money will be strictly designated to wage payments. With that in mind, approximately 9,000–10,000 (PY) can be purchased in the project management phase. Specifically, this many professionals can be hired over the life of the project, proportionate to the cost allocation for program management activities for Phase 1. The cycle of this hiring wave over the life of the project is shown in detail in figure 23, with a peak period of cost-related employment estimated during the 2016 period of 1,606 professionals (120 core design phase staff and 1,486 program management staff). It is generic modeling, based on cost constraints, based on the assumption that costs related to program management are primarily those that are incurred to bring in specialized design phase professionals to complete specific design elements and tasks.

Further, we allocate a small portion of that estimated 9,000–10,000 (PY) to actually occupy design phase jobs. The Design Phase Team remains a small portion of the Program Management Team (as 120 fixed-cost personnel continuously; darker grey line) as depicted in figure 23, and that during program management's shift to field management, that more professionals cycle into the project (variable personnel; lighter, dotted grey line, ~9,000 PY). This is done primarily to distinguish between professionals to be involved in the design phase and those in the construction management phase.

For measurement purposes, the Design Team constitutes the smaller, straight line as shown in figure 23, and the Program Management professionals (as the variable dotted line) are counted separately from the Design Team, as management phase personnel. This is done to show that the Design Team constitutes a smaller personnel team, and that the Construction Management Team will have Program Management professionals who manage large portions of the project. After assembling the personnel wave as seen in figure 23, the final step of this process is to assign positions based on accepted guidance from the Technical Memorandum provided by CHSRA and based on variable-cost personnel composition estimates from industry-provided sources. Using these elements, we construct an estimate of the design phase professionals/personnel based on cost and on assumptions of that workforce. The output of this process is the "bottom-up" estimated workforce, labeled with specific job titles.

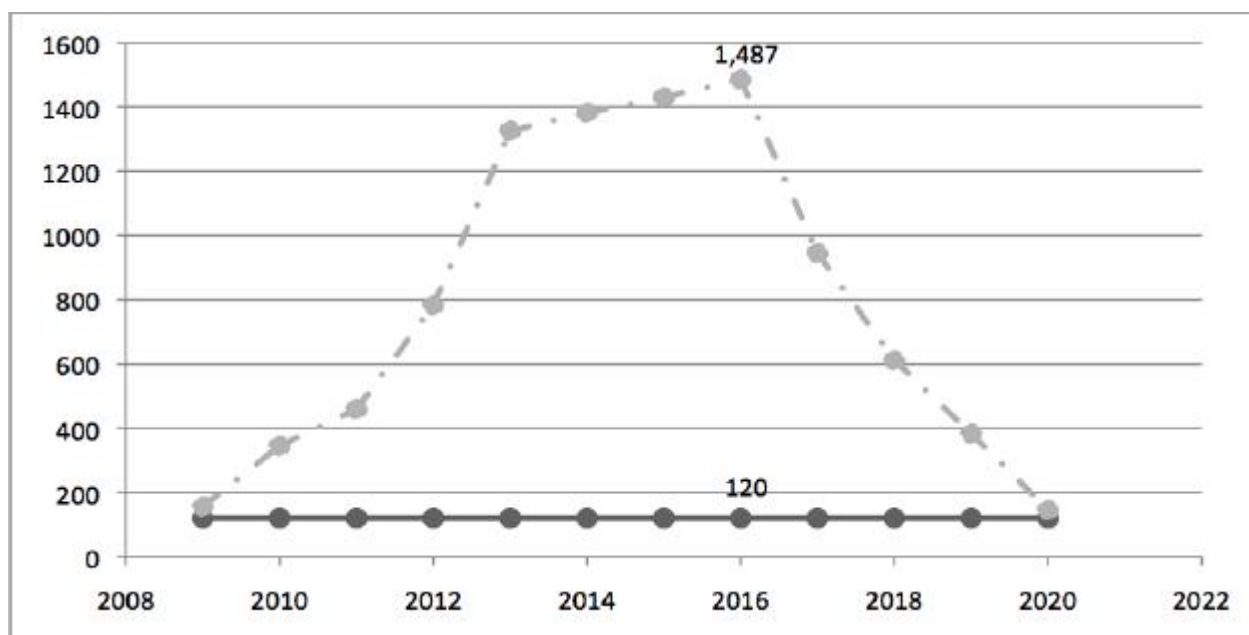


Figure 23. Design: Estimated Personnel Purchasing Capability of Program Management Team Fixed-Cost Design Phase Professionals (dark grey) and Variable Program Management Personnel (light grey)

Summary of the Design Phase Estimation

We have presented broad and flexible estimates of the number of engineering professionals and managerial construction professionals employed during the design cycle of the CHSR network build-out. We do this through estimating both a fixed cost engineering team (continuous team over the project) and with variable personnel who rotate in, based on demand and the cost cycles. Although the data do not enable us to estimate the demand of specific professionals by title, we have isolated a group of engineering professionals who are directly reflective of the CHSR cost modeling procedure.¹⁵¹ Further, we have estimated the quantity of engineering professionals needed to complete the tasks and activities of program management through comparison and inference, and modeled a plausible rotational staffing composition. We arrive at a design management personnel “purchasing capacity” to be in the range of 9,000–10,000 professionals, including estimation of direct and variable-cost staffs, over the life of the project (2009–2020). Conceptually, experts with varied background will cycle into specified projects, requiring increases and decreases in professional services. This is the maximum level of detail concerning the design phase that can be realized at this time.

CONSTRUCTION MANAGEMENT PHASE METHODS AND ESTIMATES

Construction Management (Pre-Build) Team (2011-2012)

We apply very similar methods of estimating the personnel associated with the construction management personnel who will be employed between 2011 and 2020, as construction begins and proceeds over the build-out of the project. As in the previous model, input of the cost structure into graph form results in a build-cycle pattern. Again, the overall cost of construction management is not exclusively wages; it also encompasses other elements

that are held constant. However, the basic method of increasing and decreasing personnel proportionate to the cost cycle remains valid. As there is a set group working within the construction management process, we apply mathematical constraints that allow for an accurate interpretation and estimate of how the Construction Management Team will expand and contract over the life of the project based on cost, *ceterus parabus*. (We again estimate that a portion of this Construction Management Team will be counted as design phase professionals and that the core staff engineering group and other personnel will increase and decrease according to cost.)

We assemble a concrete interpretation of the personnel affiliated with the Construction Management Team as the build-out begins to occur in the project, and apply the same \$105,178 estimate per personnel to arrive at a conservative figure of these personnel. We utilize the same types of data as outlined in table 25, and base our assumptions on:

- CHSR network cost estimation,
- Technical Memorandum provided by the CHSRA Program Management Team,
- Program Management Team size/type measurements, and
- Variable-cost personnel estimates.

Using these elements, we construct an estimate of the design phase professionals/personnel. We then apply these personnel assumptions to arrive at more concrete personnel team composition, and make inferences about the team numbers associated with the Construction Management Team process that results.

The Construction Management Team

The cost cycle for construction management occurs between 2011 and 2019, when the bulk of the infrastructure is scheduled to be built. Figure 24 depicts a major spike in construction-oriented management build-out, reflective of increases in anticipated construction activity in the system during that time. Once again, this model applies the concept of a core team of professionals (primarily engineering and management staffing), estimated at fifty-three fixed-cost design professional engineers, and allows for rotational staff (variable-cost professionals and personnel) to move in and out of designated positions, totaling 9,096 PY). It assumes that the fixed cost engineers will be design phase professionals, and that the variable-cost professionals and personnel will constitute the Construction Management Team, with a different composition based on heavier construction-related demands.

Figure 24 shows the cycle of cost allocated to the Construction Management Team, and when we apply the value of our previous estimate of \$105,178 for estimated annual cost of personnel, the pattern of professionals emerges with a specific number allocated annually. We arrive at a feasible ratio of personnel that enables estimation of the increases and decreases of personnel, proportionate to cost estimates. The peak point is projected to occur in 2017, with an estimated personnel total of 1,670 professionals (1,618 variable-cost personnel and 52 fixed-cost engineering personnel). The cycle ends in 2019, with proportionate decreases in personnel. Again, both direct cost and variable-cost personnel affiliated with the project are included in the estimate. In total, based on our constraints, construction management requires about 8,500–9,100 personnel over the 2011–2019 period.

Construction management also entails a fixed-cost team (i.e., civil engineers central to the project, as the straight dark line in figure 24, representing 468 PY, over the life of the project), which represents the design phase engineering teams, with variable-cost staff (representing 8,628 PY) who rotate in and out of the project to complete specialized tasks, representing construction management personnel.

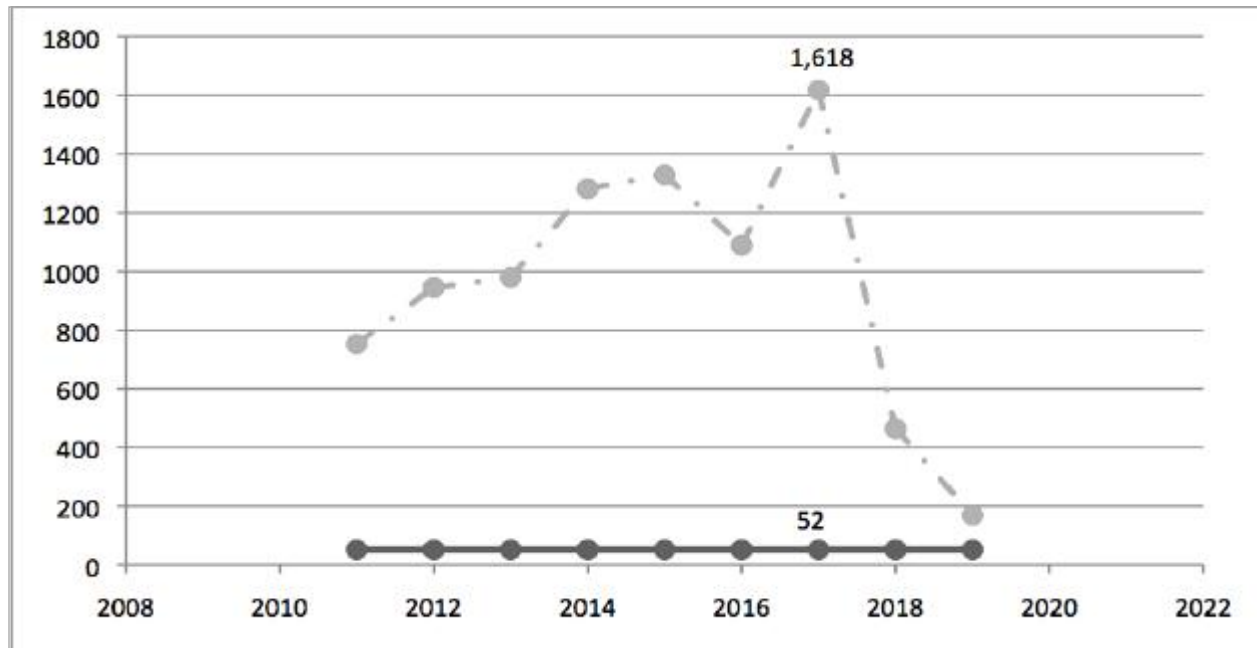


Figure 24. Construction Management Personnel Estimation Direct-Cost Staff (Dark Grey) and Indirect-Cost Staff (Dotted Line)

Combining the Program Management and Construction Management Models

We conclude by combining estimates for the Program Management and Construction Management Teams to create an acceptably accurate estimate of their expansion over time, based primarily on cost assumptions. By applying salary assumptions, we arrive at estimates of management personnel involved over the life of the project, among the two areas of management activity (program management and construction management). We also separated what we consider to be design phase professionals (as a constant and small group of professionals, represented in figure 25 as the darker straight line), from the construction management phase personnel (as the variable-cost personnel). This is done to connote the smaller, but continuous, role of design phase personnel over the life of the project. Figure 25 represents the total numbers of program management and construction management personnel, drawing distinction between the design phase and the construction management phase. The construction management phase is represented by the dotted lighter grey line, and the straight line represents the design phase, which is continuous over the life of the project.

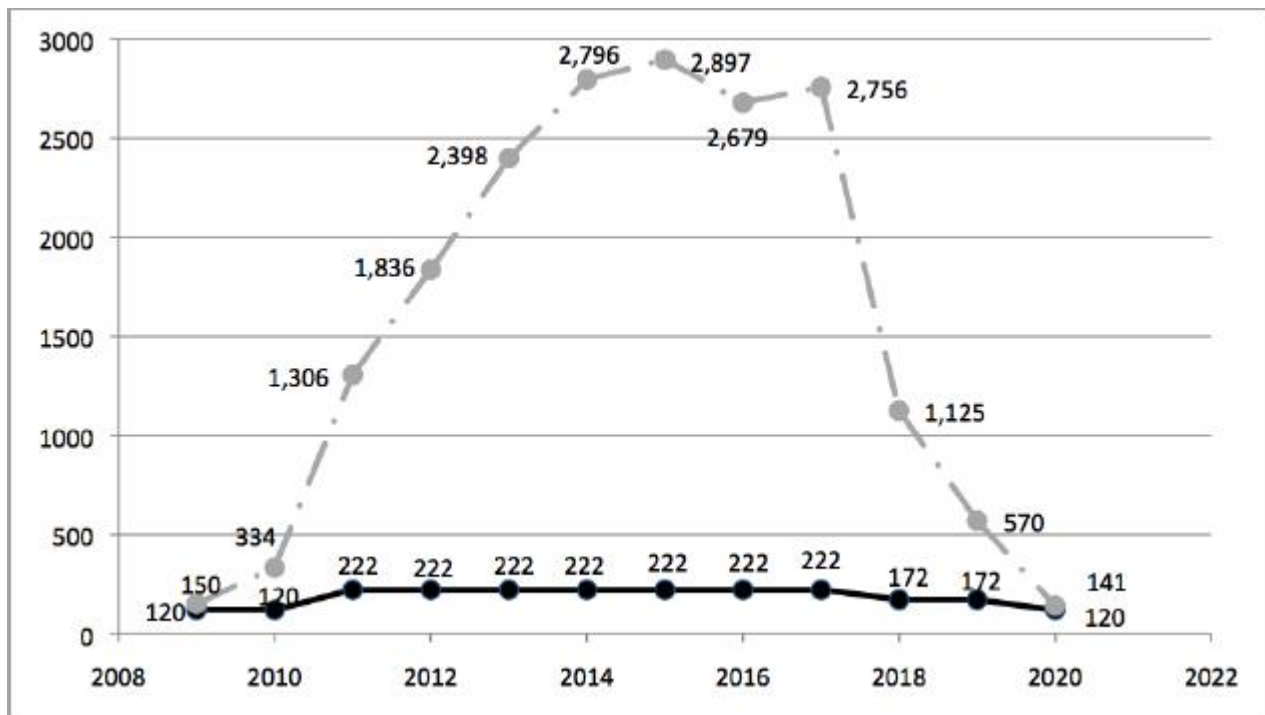


Figure 25. Total Program Management and Construction Management Personnel Demand: Estimates of Personnel Through Fixed Cost (Solid Line) and Indirect Costs (Dotted Line)

Overall

Overall, the demand for professionals/personnel needed over the two phases translates to an estimated total 19,880–23,388 personnel, based on cost the cost cycle, over the life of the project. For the smaller (design) phase, the black straight line in figure 25, there are an estimated 2,214 to 2,258 professionals/personnel needed specific to the design phase over the life of the project. Together, program management and construction management (constituting the construction management phase) are estimated to require 18,500–19,000 professionals/personnel, reflective of the larger amount of professionals/personnel needed in the construction management phase. Compared to our initial top-down estimate of around 22,324–23,443 PY, the ratios are similar enough to accept the much more detailed, bottom-up workforce composition.

Analysis of Program Management and Construction Management Estimates

Although our estimates of design, program management, and construction management personnel required for the project are by themselves specific enough with respect to job title and expertise, personnel lists obtained from industry enables the assembling of hypothetical teams that will be comprised of personnel affiliated with the two management processes. Specifically, combining various types of information at our disposal (e.g., industry-provided data, indirect personnel cost-estimation data as well as data from the December 2009 BP Report to the Legislature (that has reasonably detailed direct professional/personnel elements) enables plausible estimates over the life of the project, and the types of professionals employed to complete general engineering tasks as well as specific roles. In addition, the 2009 BP Report stated possible ways in which the program

management may function as oversight during the shift to the construction management phase, and highlights a framework through which to speculate on the composition of the affiliated design personnel/professional groups built into our model during that transition.

More specifically, the Program Management Team has outlined a scenario in which the final Design and Construction Management Team builds from the existing base of the Program Management Team, and therefore inferences about the composition of this segment of the workforce can be applied, recognizing that the teams will increase proportionately to the specific regional needs of each section of the systems' build. As noted by the Program Management Team: "Regional Managers" would remain in charge of the work in their section, acquiring additional staff as needed to manage the right-of-way work, the final design/construction, testing, and commissioning and revenue service start-up. Led by a program director, the Program Management Team:

*will be structured to provide both headquarters and field office staffs responsible for managing final design/construction and the operations & maintenance (O&M) contract procurement and administration, right-of-way (ROW) acquisition, construction management, engineering and environmental management, safety, quality assurance/quality control (QA/QC), program administration, program controls, testing & commissioning, revenue service start-up, and planning/oversight of the O&M of the completed system.*¹⁵²

In sum, Program Management staff are prepared to move to the construction management sequence, and this workforce composition will change as the need for personnel/professionals increases.

Summary of Design and Construction Management Phase

In sum, the cost-based personnel estimation captures three major elements associated with the workforce needs of the design and construction management phases: (a) those currently working in the project (as direct personnel), (b) the preeminence of engineers in the planning process, and (c) continuous personnel (the engineers) and rotational personnel (specialists, consultants, and managers) who are involved over the life of the project. Clear distinction between the Design and Construction Management Teams is drawn, and estimated need for personnel during both phases is calculated.

Build Construction Phase Methods and Estimates

In contrast to the design and construction management estimates, which are more general, the available data enable the much richer bottom-up estimation we outlined earlier for the build construction phase (which entails the bulk of the personnel/professionals needed in the CHSR project). They can provide detailed types of estimated personnel, by type of element that needs to be completed, and are sensitive enough to measure personnel/professionals per mile of project construction, or per an element (bridge, tunnel, etc.) estimate. The bottom-up methodology is a reverse engineering process, with which we target the measurement of labor affiliated with the cost structure, as presented by the CHSRA, for Phase 1 of the project.

This method enables accurate and project-specific estimates of personnel (including detailed crew composition), by length of track, and by the type of element that needs

to be constructed in any HSR system, and provides us with insight into the workforce needs associated with different elements within the project. It further enables prediction of the composition and quantity of that personnel over the distance of 1 mile (e.g., track, or by type of earthwork needed to be completed) or by type of element that needs to be constructed (e.g., by station, or by power infrastructure elements, etc.). This approach can more generally be applied to other corridors (with appropriate adjustments related to cost applied) to estimate the type and number of personnel needed to develop HSR infrastructure across the nation.

Bottom-up methodology also enables us to adjust for the emerging changes in the CHSR project as they occur, such as proposed shifts specific to Central Valley, changes connected to the build sequencing, and the time of delivery of the project. To discuss details of the labor analysis process, we outline the bottom-up estimation method. Specifically, we discuss the linkage between unit prices and takeoff factor, and their connection to the labor method.

Unit Prices and Total Cost

We utilize unit prices and takeoff factors as the means to identify details connected to the labor force. Unit prices are used as a means to set total cost. This also is true for the cost structure as outlined by the Program Management Team for the CHSR project. The development of individual or composite unit prices is drawn from historical bid data and by unit cost analysis, as appropriate, using labor, equipment, and material rates. The unit price analysis method will typically be used to develop comprehensive cost estimates for complex construction elements such as tunneling, aerial structures, underground structures, and so on. This method allows for unit prices to be developed based on current local construction and market conditions such as changes which might affect productivity or the cost of labor or materials. The basic equation presented in figure 26 allows us to set a unit price. As seen in figure 26, labor is a component that is built into the cost equation that helps to set unit prices and increases and decreases in labor, and can cause proportionate increases and decreases in cost.

$\text{Total Cost (by Unit Price)} = \textit{Labor} + \text{Equipment} + \text{Material} + \text{Efficiency} + \text{Time} + \text{Overhead} + \text{Other Factors}$
--

Figure 26. General Equation for Total Cost (By Unit Price)

Unit Prices and Labor Needs (Takeoff Factor)

Focusing on the labor variable (in bold and italics) as shown in figure 26, unit prices (total cost) are set according to specific project needs, through the use of what is known as the *takeoff factor*. Specifically, the takeoff factor is an equation that sets incremental measurement for the elements included in the unit prices (i.e., labor, equipment, material, efficiency, time) so that they can be measured over a specific distance/element.¹⁵³ This is a tool used by cost estimators and construction managers, and is conducted to measure the estimated amount of labor, equipment, material, and so on that will be needed to complete specific distances/elements. Labor estimators also use the takeoff factor to set quantities of items needed to complete a project to prepare the labor portion of a cost estimate.

The takeoff factor can be set to the desired length or by a desired element, specific to the estimation of the labor needs (on a per-segment, per mile, per-element basis). Further, focusing exclusively on the labor element of the unit price, and manipulating the takeoff factor (i.e., increasing the measures proportionate to the CHSR projection), we are able to focus on the estimation of labor associated in the CHSR network build. Figure 27 outlines the takeoff factor equation, recognizing labor and time as components.

$$\text{Takeoff Factor} = \text{Labor Quantity Needed} + \text{Equipment Needed} + \text{Materials Needed} + \text{Efficiency of Labor/Equipment} + \text{Time To Complete} + \text{Other Factors}$$

Figure 27. Takeoff Factor, Generic Equation

Defining Bottom-up Methodology

Thus, the linkage between costs and labor needs is built into the cost structure of the CHSRA cost projections and can be manipulated using the takeoff factor, for further analysis of the quantity and type of labor needed (i.e., so that we can set the takeoff factor proportionate to elements that we need to measure, and measure the associated labor output). By conducting a labor-specific analysis, we can identify the labor needs proportionate to the cost structure as outlined by the CHSRA, identifying direct labor needs within the system.

The linkage between unit price and the takeoff factor is central to understanding how the bottom-up estimations are created. Bottom-up estimation methodology is a variation upon existing unit pricing, commonly used in firm cost-setting (by unit price) practices. It uses the takeoff factor, adjusts the takeoff factor for a specific distance, and examines the labor composition that results. Therefore, with analysis of industry-provided unit price documentation, labor composition documents, and independent estimates specific to the CHSR network, we can construct accurate models that depict labor-specific estimates and composition, proportionate to the cost structure as released by the CHSRA. There are multiple steps taken to appropriately model the labor workforce, discussed next.

Steps of Bottom-up Analysis

In figure 28, we discuss the methodology of measuring the CHSR construction phase workforce. The six major steps presented next subsume the procedure of developing the bottom-up estimates.¹⁵⁴

Step 1. Using the cost estimates outlined by the CHSRA, the first step is to benchmark an acceptable rate of direct personnel according to APTA direct measurements, creating a curve that represents direct jobs required for the project, according to the CHSRA data.

- Output: direct measurement of personnel wave, applying the APTA measurements of direct personnel (i.e., quantity benchmark for all build personnel).

Step 2. Set personnel ratios, by mile and by element, through manipulation of the takeoff factor. Using unit cost pricing documents, set cost estimation data to measurements that can be further applied to the CHSR network model (i.e., adjust all elements to measure per mile/per element, over a set period of time, adjusting the unit cost pricing documents to reflect labor estimates, per mile/per element).

- Output: labor estimates that can be applied to the CHSR model, on a per-mile/per-element basis, referring to a specific period of time.

Step 3. Measure the CHSR model, identifying all known elements of project (e.g., miles of track, buildings, bridges, tunnels, etc.), and use the labor estimates from Step 2 to create a list of personnel, by mile and by element.

- Output: total personnel needed, before adjustment for time.

Step 4. Adjust cost estimation measurements to reflect the time constraints of the CHSRA model, adjusting for the time frame of the project.

- Output: aggregate estimate of personnel needed to complete system (Total CHSR personnel, within the needed time frame).

Step 5. Deploy Total CHSR personnel (by element and by mile) over the life of the 2012-2020 project period, according to the cost structure of the CHSR project.

- Output: project workforce estimate, by personnel, by element/mile, over time (2012–2020).

Step 6. Confirm that project workforce estimate and the APTA direct measurement benchmark from Step 1 have acceptable characteristics and personnel ratios. This is done to make sure that the measurement output appears as similar as possible to the benchmarked direct personnel estimation.

Figure 28. Bottom-up Labor Estimation Steps

Steps of a Bottom-up Estimate as a Sequence Map

These steps also can be written out as a sequence map as shown in figure 29, with a figure that represents their outputs. In this figure, we follow the sequence as shown earlier, and begin with Step 1 as shown in the upper left corner. Here, we (a) set a benchmark of the

direct personnel we anticipate to be able to measure; (b) obtain cost estimation data, and adjust it to be able to measure labor, by mile; (c) measure out a detailed CHSR route, based on the 2009 BP Rote Modeling; (d) design a set of detailed CHSR, per mile, per element, measurements, based on defined CHSR elements outlined by the Program Management Team; (e) adjust the labor model to the time frame needed to deliver project; and (f) adjust the total PY estimate, by element, over the life of the project. In the figure, the white lines represent steps taken, and the black lines represent the outputs at each step. The final step (as depicted with a star) shows the comparison of the top-down estimated workforce (from Step 1) to the more robust and detailed analysis of the bottom-up measurement (from Step 6). The output confirms that our bottom-up labor estimate is within acceptable benchmarked ratios, and provides new project workforce details.

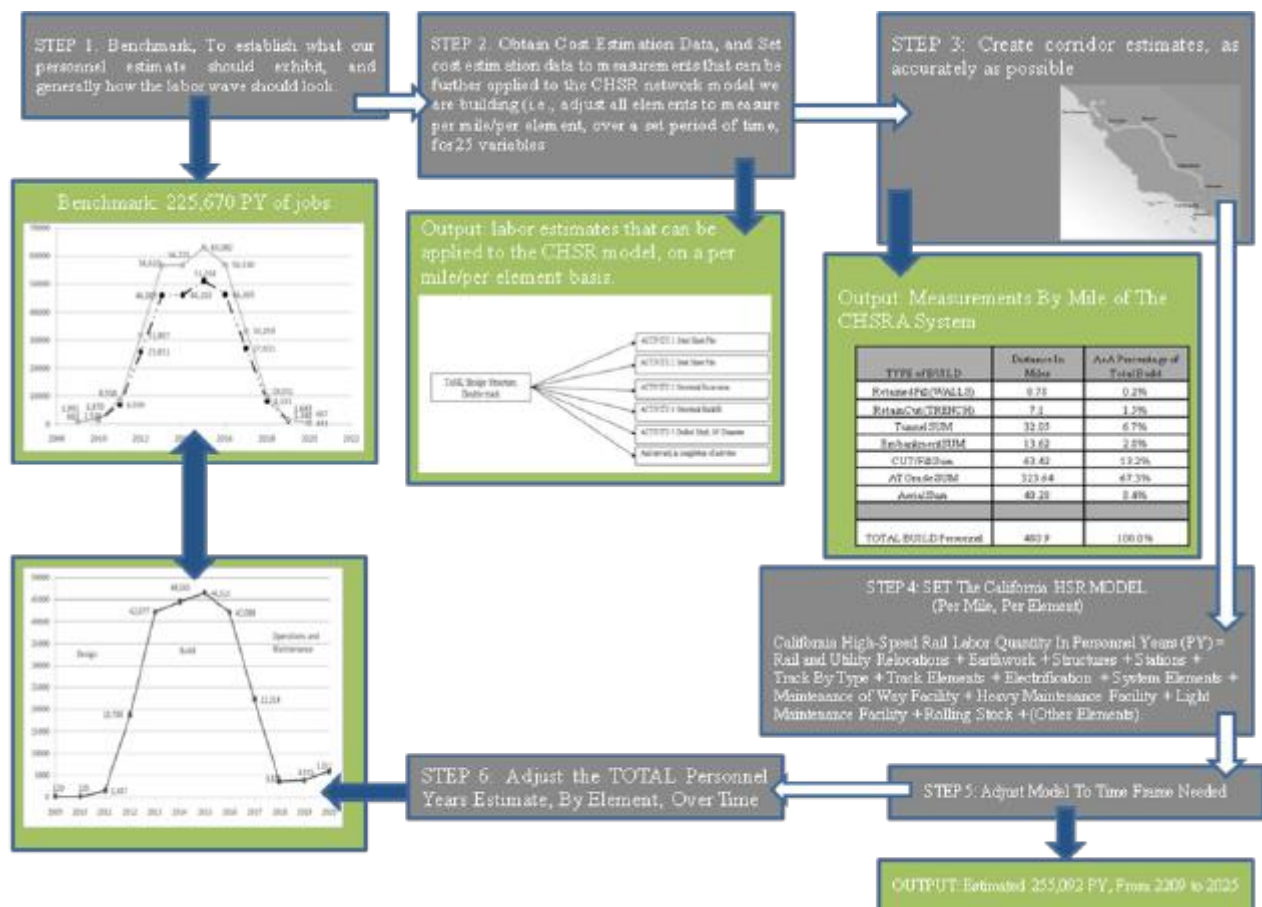


Figure 29. Bottom-up Measurement Sequence, Graphical Representation

Each of the six steps represents a critical aspect of measuring the workforce using the bottom-up methodology. Next, we discuss the steps in more detail.

Step 1

In Step 1, where we set a benchmark of the direct personnel we anticipate to be able to measure, we constrain our model to be able to measure only direct personnel within certain ratios connected to the cost structure. Without this measurement that benchmarks the direct personnel workforce, there would not be a method to compare the outcome as shown in Step 6 to anything, and the model would have limited application to the real project. Second, this benchmark establishes the first assumptions behind the “personnel wave” over the life of the project, where project labor increases and decreases over the life of the project. Therefore, the first step is critical in framing and limiting the amount of direct personnel we should be able to find in the model as well as setting up the initial personnel wave for future comparison.

Step 2

In Step 2, where we obtain cost estimation data and adjust it to be able to measure labor, by mile, we establish a method of measuring the CHSR network, as a labor ratio. Specifically, through setting our cost estimation data and takeoff factors to labor-per-mile measurements, we establish a method to extrapolate larger, labor-specific assumptions, mile-by-mile, across the entire CHSR network model. (The system is scheduled to be over 500 miles in Phase 1.) A major element to this is that these labor estimates are set to a PY ratio, meaning that we measure how many personnel are expected to be needed to complete a specific task and activity, within the distance of a mile. Intermittently in this step, based on varied tasks and activities, we also identify detailed team compositions, based on the different elements that need to be constructed in the CHSR network. Therefore, a subset of Step 2 also involves identifying and assembling these personnel compositions, based on a range of tasks and activities that need to be completed.

Step 3

In Step 3, where we measure out a detailed CHSR route, based on the 2009 BP Rote Modeling, we set up a mathematical representation of the system elements that need to be constructed to complete the system, on a mile-by-mile basis, over the entire state, using Global Information Systems (GIS) mapping software. Here, we measure out a system that is 488 miles long (to represent Phase 1 of the network, and is considered highly accurate), and the Los Angeles to San Diego region, for potential future analysis. This mile-by-mile GIS map allows us to construct a representative CHSR network model, based on the major elements that need to be constructed. Hence, Step 3 provides us with details about what needs to be constructed, mile-by-mile in the CHSRA system, as an intermediate step to setting up a labor equation to identify the total direct personnel needs in the system.

Step 4

In Step 4, we construct the labor equation designed to represent the major elements that are to be constructed in the system, which measures the types and quantity of direct labor needed for the completion of the CHSR network. The equation is set up according to major elements that will be constructed in the system and is expanded upon through identifying

other elements that will be in the system, based on extensive review of CHSRA Technical Memorandums. These Memorandums provide details about the types of structures, needs-per-mile, and other elements needed to complete the network, and we can specifically identify the labor needed to construct these specific elements. The CHSR Network Labor Model equation is shown in figure 30. The intermediate output of the labor equation is adjusted, as discussed in Step 5. These measures are set on a per-mile and per-element basis to focus on the labor element.

CHSR Labor Quantity in PY = Rail and Utility Relocations + Earthwork + Structures + Stations + Track By Type + Track Elements + Electrification + System Elements + Maintenance-of-Way Facility + Heavy Maintenance Facility + Light Maintenance Facility + Rolling Stock + (Other Elements).

Figure 30. CHSR Labor Quantity in PY

Step 5

In Step 5, we adjust the labor model to the time frame needed to deliver the project, increasing PY to complete the project within the scheduled window of delivery. In our model, this is the 2009–2020 period, although new modeling changes the total period of delivery for the project (i.e., extending the project into the 2033 period, in some models). This is critical because some of the elements listed earlier (specifically stations, tunneling, and aerial structures) have massive labor estimates that exceed the time frame allocated, unadjusted (i.e., some larger estimates anticipate the need for 5,500 workers over a 55-year period). However, since we are not allocated 55 years to construct the project, we have to increase our labor, proportionate to the time frame needed to complete the project. This incremental adjustment was applied to about half of the total elements discussed earlier, and in compliance with cost projection information which detailed the time-frame delivery of project elements. This increased the total estimated PY needed over the life of the project. The output from this process is the total direct personnel needed within the time frame allocated to the project.

Step 6

In Step 6, we redistribute the total direct personnel estimate from Step 5, across the labor model, proportionate to the cost structure ratios, over the 2009–2020 period. Over time, the project has different increases and decreases in cost, and we accept these fluctuations as representing labor patterns over the life of the project. Specifically, each element as shown in figure 30 has varied cost patterns, per the 2009 BP cost structure/model. In Step 6, we incrementally adjust the total PY estimate, by element, over the life of the project. The output is detailed direct labor estimates, over time, and confirms that our bottom-up labor estimate is within acceptable benchmarked ratios and provides new project workforce details.

Step 7

The outcome of the six steps produces estimates of PY, by phase and by profession/personnel, over the life of the project. This functions to show the labor demand over the life of the project. At this time, we still deploy the 2009–2020 model, and will make appropriate

adjustments according to the impending release of a new CHSRA BP. The final step involves comparing our APTA top-down ratio, as defined in Step 1, to our new estimates from Step 6. The outcome as predicted identifies that we have created acceptable ratios of direct personnel over the life of the project. Accepting the PY estimate from this process, we estimate 202,000 direct job build construction personnel, in the sequence shown in figure 30.

Total Outcome Build Construction Estimation

As depicted here, the total direct personnel needed to construct the CHSR elements that we have analyzed is well over 202,000 direct personnel jobs, between 2009 to 2020. Accepting this measurement quantity as representing the build construction phase personnel/professionals, we transition to measuring the final phase of the project: the operations and maintenance personnel.

OPERATIONS AND MAINTENANCE METHODS AND ESTIMATES

The estimation method used for the operations and maintenance portion of the project is notably different from the three phases that precede it. The CHSRA has most recently estimated 4,520 personnel/professionals to be affiliated with the operations and maintenance sequence. Under the CHSRA estimates, train maintenance overhaul personnel involve 1,500 people, or approximately one third of the workforce. These personnel will be trained in basic body and paint shop work, upholstery, and fabric, and will have mixed skills similar to aircraft mechanics, systems and electrical engineers, and technicians. The CHSRA has projected that these personnel will have training, including a four-year technical degrees plus specialized HSR training, and that high-tech skills are important.

The second group of professionals will be responsible for the Maintenance-of-Way roles such as track, ballast, power systems, signaling, and telecommunications as well as structure maintenance. This group is estimated to consist of 440 employees, or approximately one tenth of the workforce. There will be specialized training for some, with education/training similar to that of utility lines people, cable installers, information technology people, and road maintenance crews. It is projected that high-tech skills will be important for about one half of the positions.

The third group includes the ticketing, security, passenger, headquarters management, and administration teams, estimated by the CSHRA to consist of 1,100 employees, or one fourth of the operations and maintenance workforce. These positions include a broad range of personnel such as security staff and ticket machine maintenance workers to those in customer service, accounting, finance, scheduling, and administration.

The fourth group consists of the drivers, conductors, and onboard service personnel estimated to be 880 persons (or one fifth of the work force). These skills are similar to today's railroad personnel, although the training regiment and preparation are expected to be more rigorous, similar to that for airline personnel. For these positions, high-tech skills are projected to be important.

The last group consists of operations control and power management personnel, estimated to be one hundred people, with skills in specialized training related to railroad dispatching, in positions similar to air traffic controllers.¹⁵⁵ These will be utility-load management type

positions in which high-tech skills are important. Table 26 contains estimates of the potential composition of this operations and maintenance workforce. We estimate a total of 4,020 personnel/professionals needed to operate the system, with a maximum need of personnel around 4,950 PY, with 4,500 PY representing the middle range of this estimate. Table 27 contains estimates of the operations and maintenance sequence professionals/personnel required to run the train system.

Table 26. Variations of Operational and Maintenance Estimates, CHSR Network (2020 onward)

Phase 1 Transportation Operations Staffing Estimates			
	Reduced Estimation	Baseline	Upper Range
Engineer	247	263	303
Train Crew	647	688	792
Service Station Attendant	293	311	358
Yardmaster	16	17	20
Dispatchers	53	56	65
General & Administrative, Management	122	130	150
Total Operational Staffing	1,378	1,465	1,688
Phase 1 Maintenance-of-Way and Infrastructure Staffing Estimates			
Track	183	195	234
Traction Power/Overhead Catenary System	141	150	180
Signal/Train Control	38	40	48
Communications	33	35	42
Bridges & Structures	24	25	30
Material Control	33	35	42
System Support	88	94	113
General & Administrative, Supervision	56	60	72
Total Maintenance-of-Way	596	634	761
Phase 1 Maintenance of Equipment Staffing Estimates			
Car Inspectors/Cleaners	685	728	834
Inspection/Repair	647	688	794
Heavy Maintenance	528	561	645
General & Administrative, Management	186	198	228
Total Maintenance of Equipment	2,046	2,175	2,501
TOTAL HSR Operations and Maintenance Personnel	4,020	4,274	4,950

The personnel listed in table 26 include four major groups who will be responsible for the delivery of operations and maintenance: Transportation Operations, Maintenance-of-Way Infrastructure Staffing Estimates, Maintenance of Equipment, and General Operations Management and Administration.

Maintenance of equipment staffing is the largest estimated group of personnel (1,378–1,688 personnel); the smallest group will be associated with the Maintenance-of-Way

staffing (596–761 personnel). Current plans call for a flexible sliding scale of the number of required personnel/professionals, which is represented as a base range and an upper range. Into our operations and maintenance model, we insert a 4,950 personnel estimator that was provided by Program Management¹⁵⁶ from the 2019 period onward to measure the estimated maximum amount of personnel who will have to be trained during the life of the project. Accepting the 4,950 PY to adequately represent the demand of personnel on an annual basis (i.e., the number of jobs needed to operate and maintain the system in the 2019–2025 period, annually), we use this higher figure of PY to examine the education needs created by the 4,950 people involved in the CHSR network.

Operations and Maintenance Estimates Determined to be Within Acceptable Ratios

Through general analysis conducted in this project on a personnel-per-mile comparison and through analysis confirmed in the 2011 BP, the ratios of operations and maintenance personnel appear to be adequate. Most recently, the CHSRA set newer operations and maintenance costs (and presumably employment figures), based on a wide range of foreign comparative models. As stated by the CHSRA, using the operations and maintenance unit cost prices developed for each cost line item, operations and maintenance cost forecasts were developed on an annual basis for each operable section in 2010 dollars. As seen in figure 31, seven international rail system providers provided information to assist in the cost-setting assumptions as outlined by the CHSRA.

Exhibit 7-1. International counterparts the Authority consulted to improve O&M costs

Issue	Belgium	China	France	Italy	Japan	Korea	Spain
Shared use of tracks in congested urban corridors	✓	✓	✓	✓	✓	✓	✓
Trainset length/coupling multiple trains	✓		✓				✓
Schedule with clock-face operation	✓	✓	✓	✓	✓		✓
Number of trains per hour during the peak	✓		✓	✓	✓		✓
Dwell time at stations	✓				✓		
Hours of service operations	✓		✓	✓	✓	✓	✓
Approach for maintaining the rail line	✓	✓	✓	✓	✓	✓	

Figure 31. CHSRA Release, International Counterparts the Authority Consulted to Improve Operations and Maintenance Costs¹⁵⁷

Combining DBOM Phases, Total Direct Personnel

The final step toward completing the DBOM labor curve is to combine all personnel estimates of each phase. The curve depicted in figure 32 depicts the combined DBOM cycle, over time, and represents the estimated workforce direct personnel and demographic over the 2011–2020 period. Note that it resembles the initial estimations related to the project delivery sequence. The design phase (bottom left) depicts the preliminary design phase.

This is an engineering-heavy time frame, where procurement documents and clearances are conducted by a small and specialized series of engineering staff. We anticipate an increase in personnel beginning in September 2012, when project goes to ground in the Phase 1 model. Moving toward the middle of figure 32, at this point, the project has been given to construction managers and their assembly teams, and massive labor is used from 2013–2016 and then begins to decrease in the 2017–2018 period. Beginning as late as the 2018–2019 period (but most likely before), trained operations and maintenance personnel (estimated at 4,950 PY annually) will begin their function as those who operate the system.

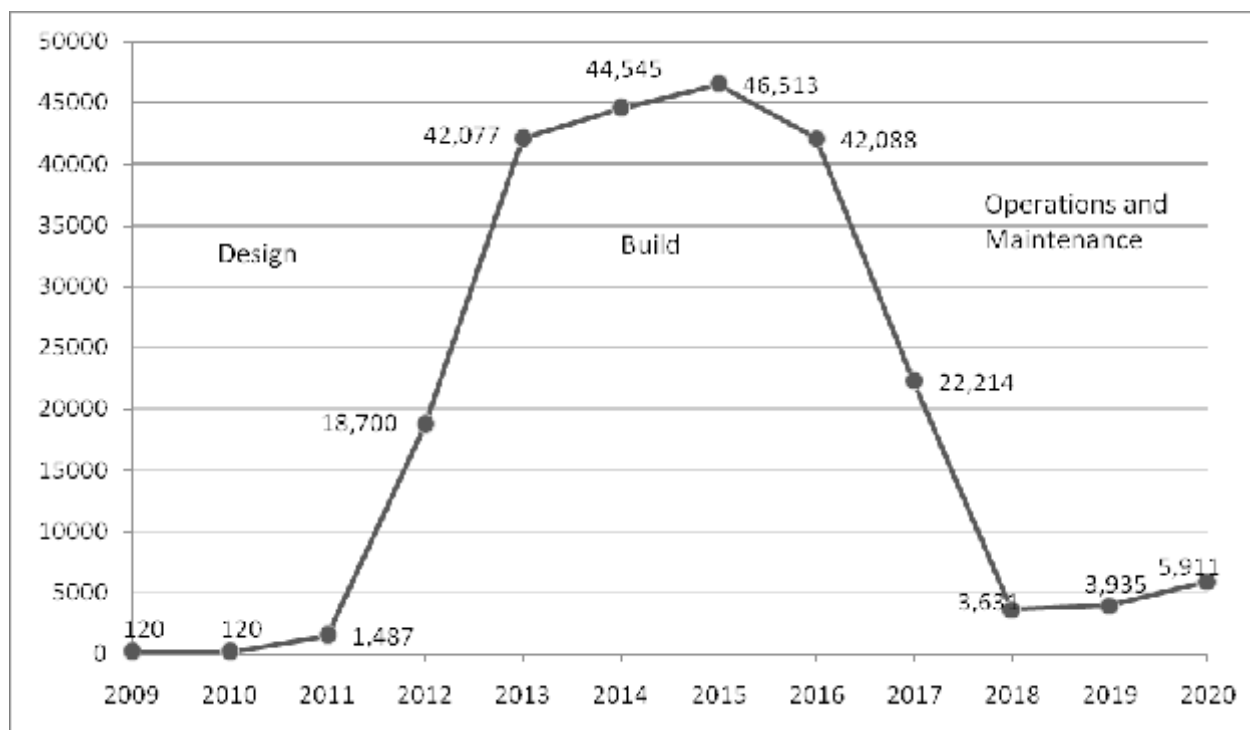


Figure 32. Design and Build to Beginning of Operations, 2009–2020, Employment Estimations

What emerges from the aforementioned process are the preliminary estimates related to the project delivery sequence associated with the DBOM of the CHSR network for direct personnel in the project. Each estimated PY is connected to a specific position and can be traced back to very detailed assumptions applied that were used to build the complex labor model (i.e., each is linked back to specific tasks and activities).

Summary

We synthesize the three different methods that are used to measure the personnel needed over the life of the project in table 27. The table provides an overview of each method, including how it is measured, whether it is basic or complex, and its smaller components of measurement, to highlight the level of detail that is achieved. Totals in PY also are shown.

Table 27. Measurement Methodology Used to Measure Personnel, by Phase (DBOM)

Trait	Design Phase	Build Management Phase	Build Construction Phase	Operations and Maintenance
How measured?	Measured applying economic principles such as the ability to purchase a unit—in this case, personnel—at a specific cost	Measured applying economic principles such as the ability to purchase a unit—in this case, personnel—at a specific cost	Complex bottom-up methodology, measuring 25 CHSR system tasks, by mile and by element, by the labor needed in each activity, adjusting each for time	Based on CHSR releases of operations and maintenance personnel projections, generally verified against foreign HSR system ratios
Complex or basic?	Basic, interpretation of cost data related to cost projection for Program Management Team	Basic, interpretation of cost data related to cost projection for Construction Management Team	Complex, based on bottom-up estimation	Moderate, Based on CHSRA estimation, which is compared to foreign HSR operations and maintenance projections ¹⁵⁹
Level of detail	Establishes concept of direct and indirect personnel, and fluctuating positions of indirect personnel, according to the CHSRA cost structure	Establishes concept of direct and indirect personnel, and fluctuating positions of indirect personnel, according to the CHSRA cost structure	Creates complex measurements based on elements that need to be constructed in the CHSR network, based on the type and quantity of personnel needed to complete tasks and activities within a specific time frame	These data represent a range of 4,020–4,950 personnel needed to conduct operations and maintenance of the CHSR network, in Phase 1, according to job type and description.
What are components? What is the output/result?	Two levels of measurement: The direct-cost professionals are considered engineering staff, and the indirect-cost personnel are engineering-affiliated positions, representing specialization that may need to be contracted over the life of the design phase. This results in an estimate of relatively detailed personnel-to-cost estimates.	Two levels of measurement: The direct cost professionals are considered engineering and construction management staff, and the indirect personnel are various engineering, managerial, and construction advisory staff, representing specialization that may need to be contracted over the life of the construction management phase. This includes preliminary construction labor and “setup” personnel needed.	Bottom-up methodology includes twenty-five tasks measured, each task having 12–100 activities (averaging 18), and associated labor and time needed to complete the activity. As a result, each task has a detailed labor estimate that identifies the labor needed, per task. This results in ultra-detailed measurements of personnel, including the build team needed to construct the HSR trainsets.	There are four levels of operations and maintenance personnel: operations, Maintenance-of-Way, maintenance of rolling stock, and management and administration. This is extended over a six- to seven-year period.
Total (in PY)	2,213	18,500–19,000	202,000	4,020–4,950 Annual PY

The design phase estimation is measured applying economic principles, using top-down cost data supplied by the Program Management Team. It is relatively crude, and applies the concept of purchasing power with the allocated program management funds. It established the concept that there will be both a continuously employed workforce over the life of the project (i.e., engineers and engineering managers to completed all clearances, procurement documents, etc.) and rotates in complex and/or specialized personnel/

professionals. This results in an estimated 9,000 PY for these positions over the life of the project.

The build management phase is measured applying economic principles as well. It also is relatively crude, and generally applies the concept of purchasing power with the allocated construction management funds. It reflects that there will be both a continuously employed workforce over the life of the project (i.e., engineers and engineering managers to assure quality controls) and rotates in complex and/or specialized personnel/professionals (construction managers, construction labor) as well as general staffing needs. This results in an estimated 8,500–9,100 PY for these positions over the life of the project.

The build construction phase is extraordinarily complex, involving bottom-up methodology. It measures twenty-five CHSR system tasks (by mile and by element) by the labor needed in each activity, adjusting each for time and results in detailed and robust estimates of specific personnel.

CHSR Labor Quantity in PY = Rail and Utility Relocations + Earthwork + Structures + Stations + Track By Type + Track Elements + Electrification + System Elements + Maintenance-of-Way Facility + Heavy Maintenance Facility + Light Maintenance Facility + Rolling Stock + (Other Elements).

The outcome and results of this estimation process show the massive needs associated with the project construction. More than 200,000 PY will be involved in the build process in our estimation, which includes the build team needed to construct the HSR rolling stock.

The operations and maintenance phase is based on information released by the CHSRA regarding the composition of the operations and maintenance personnel needed. It is consistent with generally verified comparatives of foreign HSR system ratios of miles-per-personnel.¹⁶⁰ These data represent a range of 4,020–4,950 personnel needed in the following key areas: operations (e.g., those driving the trains and supporting the stations), Maintenance-of-Way (e.g., technicians, electricians, etc.), and administrative and managerial positions (e.g., accounting, fiscal management, budgetary, secretarial, etc.).

Our estimates confirm that there is an estimated 256,000 (or slightly more) direct jobs that will be created, over the project from 2009 to 2025. Figure 33 shows the distribution process, in which we combined the estimates of DBOM into a single personnel wave, as originally discussed in Section I. The figure depicts the estimated direct labor needed over the life of the Phase 1 build, and demonstrates a demand for the associated professionals/workers needed to complete the CHSR project.

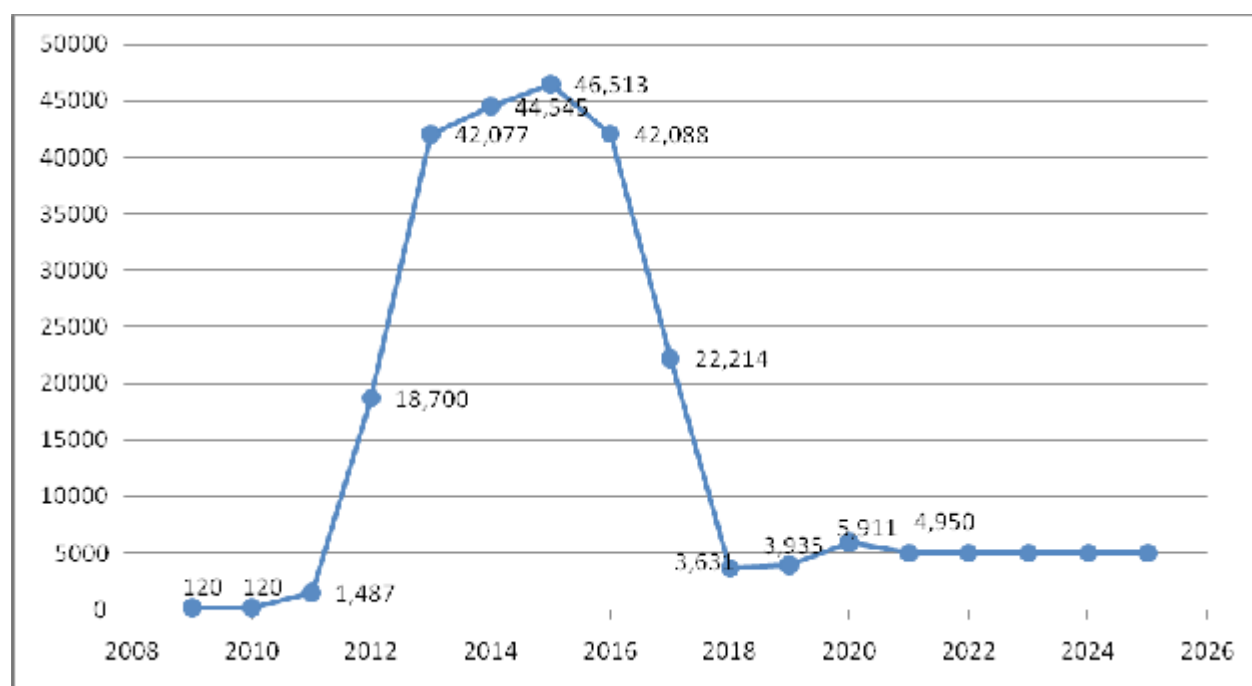


Figure 33. Direct Personnel, 2009–2025, CHSR Network, Direct Personnel

Figure 34 illustrates the combination of all project phases in a single demand wave over the life of the project. It follows the pattern that would be anticipated to emerge during the construction of the CHSR network (as per the depiction of funding for the Acela Northeast Corridor presented in Section I). The final element related to the personnel wave as constructed earlier is to compare the representation of personnel over the life of the project to the direct application of direct personnel, related to the APTA ratio, adjusted for labor-intensive processes. The data presented in figure 34 confirm that the personnel estimation that we have conducted using a bottom-up methodology follows a similar pattern of personnel deployment as the generic “top-down” estimates. Of course, it is not a direct replication of the pattern wave as benchmarked because it has the significant advantage of being able to provide insight into specific labor components distributed over time, across the span of the project.

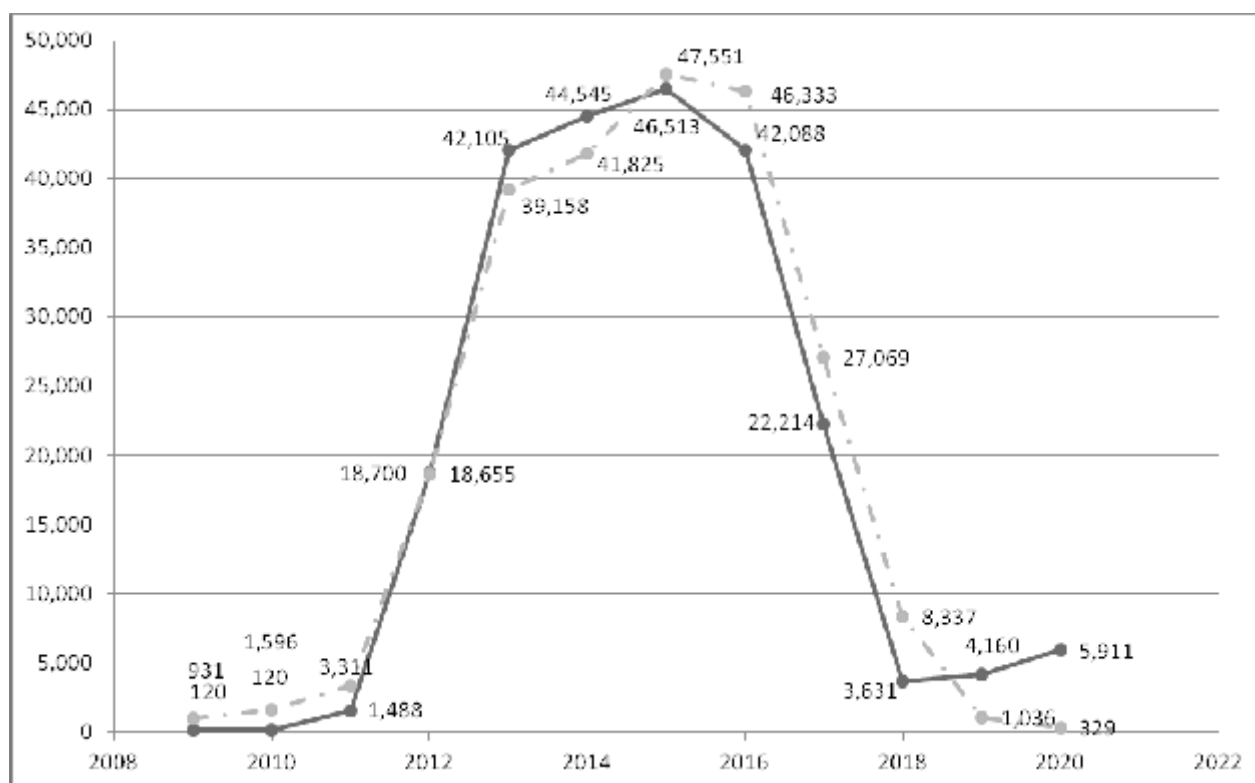


Figure 34. Mathematical Benchmark (dotted line) and Bottom-up Estimation (solid line), Personnel Wave, 2009–2020

Construction of the CHSR Workforce Impact Index

To measure HSR workforce development impacts, per se, we have designed a comparative index called the CHSR Education and Training Index. Constructed by means of identifying the laborers and professionals needed to complete the CHSR network, it is a comprehensive measurement of the education and training levels required for the CHSR workforce, over the 2010–2025 period, for the 256,000 professionals/personnel identified to be needed, as shown in figure 33. The Index establishes individual employment needs, according to individual professions, reflective of the demand for employees in the different employment patterns in the CHSR build-out. It also is designed to reflect the education composition of the personnel affiliated with the CHSR network, through comparing education level by type of position.

In addition to tapping our own estimates, the Index is derived from multiple data sources such as the U.S. Department of Labor, Employment and Training Administration, O*NET data, Employment Development Department, Department of Labor, Bureau of Labor Statistics, and EMSI data. These varied identifiers of the level of education needed to hold a given position are then compiled into the Index for analysis.

Connecting Statistical Data to Observe Training, Community College, and University Impacts

Taking the total personnel estimation (256,000+ workers/professionals), we apply education characteristics/probabilities to the workers we have estimated to be needed to complete the project, to obtain estimation of the demand for a particular level of education. There are seven levels of education that are used by the government to identify the level of education of a particular profession/job. As an example, table 28 lists the education associated with the construction laborers workforce. Note that of the 13,540 construction laborers, 36 percent of this component of the workforce will have a less than high-school education, 40 percent will have a high-school diploma (or the equivalent), 17 percent will have some college or A.A./A.S. degrees, and 4.8 percent will hold B.A./B.S. degrees.¹⁵⁹ This can further be interpreted as the probable need to train 76 percent in the trades setting, 18 percent in the community college setting, and 4.8 percent in the university setting. Table 28 shows a statistical representation of a workforce education range for each professional/personnel position in the Index, which translates into a demand for different levels of education.

Table 28. Example of Labor Education Needs for Construction Workers

Position	Less Than High School	High School	A.A./A.S.	Some College, No Degree	B.A./B.S.	M.A./M.S.	PhD	Total
47-2061.00 - Construction Laborers	4,920	5,460	515	1,982	662	0	0	13,540

Shaded areas indicate training that would need to be completed by labor training (i.e., seven of ten laborers would need this type of training) such as vocational or other training. The second level of education (A.A./A.S. to Some College, No Degree) is likely to be delivered in a community college or other learning/training mechanism. At this level, the individual would ascertain an A.A./A.S. level or perhaps certification or training in the postsecondary system, specializing in HSR-specified training. The third level (B.A./B.S., M.A./M.S., and PhD) represents the need for education at the university level, in the form of a B.A./B.S. or an advanced degree for a particular position. Again, assumptions must be applied to interpret this need for education.

Incremental Adjustments to Highlight Education Needs

After compiling education demographic data as shown in table 28, adjustments were made based on probable patterns of education. Specifically, we ignored outliers. (When the probability data were below 5 percent of the total workforce, we primarily changed the ratio to zero because it represented needs that were unlikely to be needed by the general population of the particular occupation.) This is because we had to make incremental adjustments that did not create outliers that inaccurately influenced our projections of labor demand. (Specifically, we did not want to overestimate education needs, especially related to personnel/professionals with M.A./M.S. and PhD degrees.) Next, the outlier

percentages were redistributed across the more plausible training and education needs. This was done sparingly, and only in situations that warranted such redistribution.

For example, we changed civil engineer probability to holding a B.A./B.S. degree or higher, and redistributed the probability that fell below the BA/BS level. This was done selectively across the model, with variables that had high influence on the model, and was an area of concentration that warranted an impact analysis independent from the report. (Refer to Appendix B to observe the unadjusted output related to the estimated education spread, and accompanying analysis.)

Observations

There is room for interpretation of the data as it is distributed across the education level attained model that we have assembled. Sometimes statistical probability alone does not properly identify needs and patterns related to training/education. In the case of construction laborers, college degrees are probably not considered mandatory for the position but it statistically appears likely that a non-zero percentage of construction laborers will possess four-year degrees. As a reference, there have been a range of degree representations for construction laborers, from 6 percent¹⁶¹ to 21 percent B.A./B.S. holders.¹⁶² To address this wide range of statistical difference, we have constructed a model that applies a higher B.A./B.S. ratio than the low end of this range. This higher level of education may offer an opportunity related to training and education of an already educated workforce. An applied range of probability for personnel/professionals who have attained a certain level of degree emerges to participate in the HSR workforce, from 2009 to 2025. We accept these probabilities as markers to identify larger patterns of education need, and apply the education probabilities to the quantitative data that we have assembled (specifically, the 250,000+ jobs that we have identified). By connecting the quantitative data to qualitative education probability, patterns of education needs emerge.

APPENDIX B: ASSUMPTIONS AND LIMITATIONS BUILT INTO LABOR ESTIMATES

Although we believe our estimates to be quite robust, the following factors may affect their validity. These include assumptions we have made, limitations of our data, and other potential sources of inaccuracy.

1. Large Level of Project Measurement

Our measurement level of project components is inherently broad, (e.g., cost per mile, per station, or per structure, etc.) and therefore lacks some precision. As the project will have many smaller elements as well, future levels of cost estimation will be likely more detailed (e.g., encompassing smaller details); the next level of measurement will provide more project-specific cost estimates, leading to more detailed assessment of the labor force needed to complete those activities. However, we do not identify any known biases associated with using the current level of detail.

2. Constrained Versus Unconstrained Funding

Funding is the fuel of any capital project. When there are fluctuations in the flow of funding into the project, the project may slow down, and less labor will be on the ground as a result. Funding patterns will heavily influence the actual deployment of HSR employees. Our model assumes unconstrained funding in the form of allocations (from the state or federal government, or other sources) that allows for the continuous deployment of workers through a continuous flow of tasks and activities. Thus, we model a project that does not cease due to limitations in funding, for the life of the project. Any breaks in funding would likely influence our estimates, as we assume the continuous influx of money, according to the project cost structure outlay released by Program Management in 2009.

3. Aggregate Personnel Versus Adjusted Personnel

Because we aim to measure total workforce impact, and not to depict workforce personnel wave from the perspective of a firm (which will adjust employment based on real-time data and output of production from employees), our model does not adjust for potential inefficiencies of output (either the need for more or less labor, based on extra-efficient or inefficient labor practices). As result, whereas the PM has stated the need for 160,000 workers, our model depicts a higher demand for workers, which may reflect the lack of inefficiency adjustments (e.g., the ability for an employee to work in multiple sections of the project, over the life of the project). This also is observed in the decision to interpret the operations and maintenance measurements as 4,950 annually, from the 2020 period, onward. This does not represent the annual need for personnel (which will be annually lower), but the total jobs created over that time period, to complete operations and maintenance tasks and activities.

In other words, the labor force may be more efficient than we expect (i.e., better trained, better equipment, stronger, more disciplined, etc., than our initial estimations assume). If so, the total number of personnel needed to complete the tasks may decrease. Inversely, the labor force may be inefficient, and more labor needed.

4. Possible Omission of More Smaller Elements from Labor Estimates

We assume that we have accurately estimated the elements in our modeling based on a series of variables; however, our model may exclude smaller elements that also will affect the size and composition of the labor force. We create estimates of the workforce needed to build out major elements of the project, assuming that the composition of this labor force will be represented by the 25 variables discussed earlier. Although our model creates robust estimates related to larger elements, smaller elements are not given any weight, as the smaller elements related to construction are impossible to measure at this point. As result, we may have underestimated the amount of specialized personnel needed in the project delivery (e.g., electrical personnel or other specialized workforce characteristics) or other characteristics associated with these smaller factors.

These smaller elements may call for additional training in specialized practices related to more detailed labor needs. Although we seek to capture as many of these smaller factors as possible, the obscure nature of some specializations within the smaller elements may not be captured in our modeling.

5. Timeline Constraints

Our model assumes that the planned project timetable, as stated in the Report to Legislature 2009, is adhered to. However, these cost elements and timelines are subject to constant readjustment. Such incremental adjustments may impact estimates of labor during peak periods, total estimated personnel, and the types of laborers and professionals needed to complete the project. In other words, our labor estimates, by design, are dependent on the time frame needed for the delivery of the activities. When the time frame is changed, the labor demand usually changes as well. When the change in time is replicated across all 25 variables that inform our estimates, there is a notable change in the amount of labor needed.

6. Changing Costs/Labor Elements Over Time

Although adjustments for materials, labor, and other cost elements are made in the CHSR project, our project cannot control for changes in cost of labor and materials over time, which may impact upon our labor estimates. As a result, our projection may not have accurately depicted the opportunity costs associated with labor/materials cost changing over time. For example, we do not calculate increases and decreases in the cost of goods based on inflation and deflation rates, and assume that there are elements of this cost estimation built into the *2009 Report to Legislature* cost-estimation representations.

7. HSR-Specific Training Needs

Although we have identified how HSR technology differs from that of conventional systems, we have not fully expressed how HSR-specific training should reflect those differences. Instead, we assume that adjustments will be made by those responsible for such training.

More specifically, we focus on identifying areas (and associated forecasts) of training and education need and not the specific forms that they take. This is because we rely on job descriptions that do not include HSR-specific information because such jobs do not yet exist. Related to this, we cannot fully depict how cost is impacted by the upcoming HSR-trained workforce. Moreover, we cannot estimate the cost of hiring the presumably

higher skilled employees who will be need to be hired. The emerging workforce may be able to demand more from the labor market, increasing costs. Applying current workforce composition to the forecast for the workforce may create a bias in our estimates that we cannot specify.

8. Probability of Education Versus the Principles of “Mutually Exclusive” Training/Education

We assume that there is a probability distribution within each type of worker or professional, and that the model that we have constructed accurately reflects it. Thus, we make assumptions about education levels based on particular positions. For example, in our data, a civil engineer will hold a B.A./B.S. 70 percent of the time, a M.A./M.S. 20 percent of the time, and a PhD 10 percent of the time. However, this assumes that an engineer will always hold a B.A./B.S.—not holding a B.A./B.S. is not an option, although in fact, some civil engineers employed by the project will probably not have a B.A./B.S. degree. Appendix B addresses extensively the impacts of the adjustments made in this manner, and identifies all related assumptions leading to the accepted workforce composition of education backgrounds.

9. Probability of Level of Education does not Imply the Total Need for Education

Since we use probability as a means to identify potential needs related to specific positions and workers, we must acknowledge that not all results presented in Section 2 constitute a need for an individual to be trained at a particular level of education. For example, just because we have a PhD need in our model does not always mean that there is a need to train a PhD for a particular profession. This is most likely to be relevant in professions that require what are considered “outlier” degrees. For example, on the whole, PhDs are held by 4 percent of the total workforce, across sectors, and M.A./M.S. holders constitute 8 percent of the total workforce.¹⁶⁴ In some professions in our model, however, this outlier is more important (in advanced engineering, advanced management, etc.). Thus, care must be taken to identify patterns of need in the output of Section 2, especially when the demand for a particular degree is very small (which needs to be interpreted as an outlier or as an extremely specialized position that suggests need for a given level of education).

10. Certain Generic Phase Assumptions, and Impacts on Labor Flow

Generic modeling and complex modeling are combined in our estimation process. Therefore, the generic workforce composition and the complex measurement of personnel are interconnected, creating a potential bias concerning the composition of the workforce. More specifically, our design phase element is generic, holding a fixed civil engineering team constant as direct cost personnel. Other design phase personnel, based on cost, fluctuate across this phase of the model. This process is repeated for the build construction management phase. Thus, our estimates reflect cost data, applying interpretations of the cost estimated directly to the personnel estimation. Although this is not the most sensitive way to determine affiliated design and build personnel, it does constrain the maximum amount of personnel who can be hired within these elements of the cost structure. In the future, it may be possible to better identify the required labor flow.

11. Technology Impact on Labor, Training Impact on Labor

Technology and education level impact the labor quantity needed; however, we hold these factors constant. As discussed in Section I of the main text, there are extensive areas of identified technological challenge and education need. Assuming technology innovation occurs and that we train/educate the future HSR workforce, this will have a direct impact in total labor needed. Traditionally, technology is recognized to have an impact on the quantity of labor needed, and it is well understood that technological and managerial advances allow for increases in productivity. This translates often to decreases in total labor needed over the life of a project; thus, we have to hold constant the implicit connection between labor and technology. Second, we extensively discuss education and training needs, which equally have an impact on the total quantity of labor needed. Education and training, traditionally, make more skilled professionals and workers. This translates strictly in an economic sense to increases in productivity, per worker, and therefore more can be accomplished with less workers/professionals. These implicit project realities must be held constant at this time, and we constrain our method of measurement to mathematical estimation (i.e., labor according to task and activities, etc.) to measure total workforce need, unadjusted for impacts of technology and education on the total workforce.

12. PY is Assumed to Mean Personnel Need

Our model implies the direct connection between PY and personnel need, which converts a labor quantity measurement into a qualitative estimate of need. Specifically, PY is an estimation of the amount of labor needed over the period of one year. For our purposes, we have assumed that this means the employment of a person/professional for the period of one year, and that this person has a certain training or education need. However, connecting PY directly to education need may be a point of future criticism.

13. Elasticity

As discussed, related to our measurement of the design phase and construction management phase personnel, we utilize a technique that identifies the purchasing power of personnel, given an allocated cost constraint. Although the general principle of having an allocated amount of funding limiting the personnel who can be hired, this economic model will inherently be more detailed at a later time. At this time, we do not have the sensitivity to know the value that accurately depicts personnel purchasing capability, and lower grade personnel costs the same as higher grade personnel, when in actuality it is cheaper to bring in the lower grade personnel than the higher grade. Our model remains generic until further information regarding the (a) crew compositions, (b) project hierarchical structure, and (c) cost estimations and needs of specific personnel are clearer. Until then, we are constrained to a model that does not have elasticity built into the personnel purchasing activity.

14. Interaction Between Technology, Labor Quantity, and Impacts

This section holds constant the interaction between technology and labor. As discussed in Section I of the main text, we argue that the creation of HSR systems will create technological demand in seven key areas. This demand, in turn, may be met by the university system, or through education/training specific to HSR technology demands. However, the interaction between technology and labor is known as the Ricardo-Hayek effect,¹⁶⁴ which identifies

the interaction (interconnectedness) between technology and labor. In this section, we do not connect qualitative discussion in the previous section to the quantitative data in this section, which would entail exploring the Ricardo-Hayek effect to fully highlight the interaction between the findings from both sections. Thus, at this time, we hold this effect constant.

ENDNOTES

1. National Taiwan University. "Railway Technology Research Center, National Taiwan University: About RTRC," (2010).
2. K. E. Haynes, C. Karlsson, and U. Blum. "The regional and urban effects of high-speed trains," *The Annals of Regional Science*, Springer, 31, no. 1 (1997): 1-20.
3. Murakami, Jin, and Robert Cervero. "Environmental and Other Co-benefits of Developing a High Speed Rail System in California: A Prospective Vision 2010-2050," Working Paper CEPP004, (UCB Center for Environmental Policy, 2010).
4. Parsons Brinkerhoff, "California High-Speed Rail Project Economic Impact Analysis Report," (October 2011).
5. Randolph, Sean. "Economic Benefits and Impacts in the San Francisco Bay Area," (October 2008), <http://www.bayareaeconomy.org/publications-list/> (accessed February 2, 2012).
6. Mahendran, Anusha and Alfred Michael Dockery. "Forecasting the Workforce Needs of the Australian Rail Transport Industry (ARTI)" Conference Paper 116148 (Centre for Labour Market Research, Curtin Business School, Curtin University of Technology, October, 2008), http://www.patrec.org/conferences/PATRECForum_Oct2008/index.php#papers (accessed February 2, 2012).
7. Mahendran, Anusha, Alfred Michael Dockery, and Fred Affleck. "A Profile of Training and Skills Development in the Australian Rail Industry" Conference Paper (Curtin Business School, Curtin University of Technology, September 2007). http://www.ecosoc.org.au/files/File/TAS/ACE07/pages/ace_papers.htm (accessed February 2, 2012).
8. Chuang, Michael Y., and William H. A. Johnson. "'Hop on board': The importation and future development of high-speed rail (HSR) in China," *Journal of Technology Management in China*, 6, no. 3 (2011): 232-41.
9. Obama, Barack. State of The Union Address, January 25th, 2011.
10. Randolph, op cit.
11. Ho, Jessie and Jackie Lin. "High speed rail commences operations," *Taipei Times*, January 6, 2007. <http://www.taipetimes.com/News/front/archives/2007/01/06/2003343562> (accessed February 2, 2012).
12. SNCF International, "In South Korea" (May 2008), http://www.sncf-international.net/52B4F302-5132-4843-85F8-625F70C984FD/FinalDownload/DownloadId-4D1C1FC1D61CDE845D359CF9985B4D64/52B4F302-5132-4843-85F8-625F70C984FD/upl/file/FP_Coree-du-Sud_GB.pdf (accessed summer 2011).
13. U.S. Department of Transportation, Federal Railroad Administration. "High-Speed Intercity Passenger Rail Program." Accessed February 2, 2012. <http://www.fra.dot.gov/rpd/passenger/2243.shtml>.

14. Ibid.
15. U.S. Government Printing Office. "49 CFR 661.21-State Buy America Provisions." Accessed February 2, 2012. <http://www.gpo.gov/fdsys/>.
16. U.S Department of Transportation, Federal Railroad Administration, op cit.
17. U.S. Department of Transportation, Office of Public Affairs. "U.S. Transportation Secretary La Hood And Illinois Officials Break Ground On Chicago High-Speed Rail Project Will Reduce Delays And Create Nearly 1,500 Jobs," Last modified October 10, 2011. Accessed February 2, 2012. www.dot.gov/affairs/2011/fra3111.html.
18. Yu, Michelle. "China to slow down High Speed Rails," Epoch Times, May 1, 2011, <http://www.theepochtimes.com/n2/china-news/china-to-slow-down-high-speed-rails-55643.html> (accessed February 2, 2012).
19. Federal Business Opportunities. "Research and Demonstration Projects Supporting the Development of High Speed and Intercity Passenger Rail Service." Last modified: July 28, 2010. Accessed February 2, 2012. https://www.fbo.gov/index?s=opportunity&mode=form&id=969909348e74d211d3eb4e2c9753f3f7&tab=core&_cview=1.
20. U.S. Department of Transportation, Federal Railroad Administration. "Railroad Safety Technology Grants," Last modified 2010. Accessed February 2, 2012. <http://www.fra.dot.gov/Pages/485.shtml>.
21. Degrande, G. "Free field vibrations during the passage of a high speed train: validation of a numerical model by means of experimental results," (Paper presented at Proceedings of the 13th ASCE Engineering Mechanics Division Specialty Conference, Baltimore, MD, 1999).
22. Viktor Krylov, Noise and vibration from high-speed trains, (London: Thomas Telford Publishing, 2001).
23. Lombaert, G., Degrande, G., and J. Bekaert. "The influence of the train speed on vibrations due to high speed trains," Noise And Vibration Mitigation For Rail Transportation Systems, Vol. 99 (2008): 19-25.
24. Yang, Y.B. Wave Propagation For Train-Induced Vibrations - A Finite/Infinite Element Approach, (eBook, World Scientific Publishing Co., 2009). Accessed at: <http://www.worldscibooks.com/engineering/7062.html>.
25. Zhang, Jie and Pan Yong. "Research on Exterior Noise Source Identification of High Speed Trains," Conference Paper, (Key Laboratory of Traffic Safety on Track, Central South University, 2011).
26. U.S. Department of Transportation. "Railroad Safety Enhancement Act of 1999." Accessed February 2, 2012. <http://testimony.ost.dot.gov/final/secfra.htm>.
27. Parsons Brinkerhoff. "California High Speed Rail Project Technical Memorandum: Structure Design Loads TM 2.2.3." Accessed February 2, 2012. www.cahighspeedrail.ca.gov.

-
28. U.S. Department of Transportation, Federal Railroad Administration. "Intelligent Railroad Systems: Positive Train Control (PTC)." Accessed February 2, 2012. <http://www.fra.dot.gov/Pages/784.shtml>.
 29. Parsons Brinkerhoff. "California High Speed Rail Project Technical Memorandum: Automatic Train Control: Concept of System TM 2.2.2.1." Accessed February 2, 2012. www.cahighspeedrail.ca.gov.
 30. ENSCO. "Autonomous Track Geometry Measurement System (ATGMS)." Accessed February 2, 2012. http://www.ensco.com/userfiles/file/Products_Services_PDF/07_Rail/Track-Inspection-Systems/090091-Rail-Autonomous-Track-Geometry-Measurement-System-ENSCO.pdf.
 31. Parsons Brinkerhoff, "Automatic Train Control", op cit.
 32. U.S. Department of Transportation, Federal Railroad Administration. Preview Information in Cab Displays for High-Speed Locomotives: Human Factors in Railroad Operations, (Springfield, VA: National Technical Information Service, 2005). Accessed February 2, 2012 at: www.fra.dot.gov/downloads/rrdev/ord0412.pdf.
 33. U.S. Department of Transportation, Federal Transit Administration. Status of the Nation's Highways, Bridges and Transit: Conditions and Performance (Washington, DC: Biennial Issues, 2008), tables 3-35 and 3-36. Available at <http://www.fhwa.dot.gov/pubstats.html> (Accessed June 25, 2010).
 34. U. S. Government Accountability Office. Report to Congressional Committees-Rail Safety: Federal Railroad Administration Should Report on Risks to the Successful Implementation of Mandated Safety Technology, (Government Accountability Office, 2010). Accessed June 25, 2010 at: www.gao.gov/new.items/d11133.pdf.
 35. Bousquet, Paul. United States Department of Transportation, Research and Innovative Technologies Administration, Volpe National Transportation Systems Center. "Use of New Technology for Highway Rail Intersections and Train Control." Working Paper. (Western Regional Safety Grade-Crossing, Training Conference, Costa Mesa, CA, May 3, 2005).
 36. Parsons Brinkerhoff. "California High Speed Rail Project: Technical Memorandum: Summary Description of Requirements and Guidelines for Heavy Maintenance Facility (HMF), Terminal Layup/Storage and Maintenance Facilities and Right-of-Way Maintenance Facilities TM 5.3," August 2009. Accessed February 2, 2012. www.cahighspeedrail.ca.gov.
 37. California High-Speed Rail Authority. "Project Scope and Vision." Last modified 2010. Accessed February 2, 2012. http://www.cahighspeedrail.ca.gov/project_vision.aspx.
 38. Parsons Brinkerhoff. "California High Speed Rail Project: Technical Memorandum, Overhead Contact System Requirements, TM 2.2.2.1." Accessed February 2, 2012. www.cahighspeedrail.ca.gov.
 39. Wang, Lan. China Academy of Railway Sciences, "Railway Research and Technology in China Today." Accessed February 2, 2012. globalview.uic.org/docs/meeting_dec06/7_wang_cars.pdf.
-

40. Parsons Brinkerhoff, "Automatic Train Control", op cit.
41. Park, Jung Ho, Chi, Heon Cheol, Seub Lim, In, Kim, Geun Young, and Jin Soo Shin. "Korea Integrated Seismic System (KISS) and Earthquake Monitoring for Korea Train eXpress (KTX)". Presentation to EGU General Assembly 2010, (May 2010): p.9850.
42. International Union of Railways. "UIC Leaflet 791-1 RI: Maintenance guidelines for overhead contact lines", 2004. Accessed February 2, 2012. www.uic.org/com/IMG/pdf/UIC_Leaflet_791-2.pdf.
43. Mahmood Fateh. Federal Railroad Administration, "On-line High-speed Rail Defect Detection – Phase III," October 2005. Accessed February 2, 2012. www.fra.dot.gov/downloads/research/rr0507.pdf.
44. Parsons Brinkerhoff. "California High Speed Rail Project: Technical Memorandum: Terminal and Heavy Maintenance Facility Guidelines TM 5.1," (August 2009.) Accessed February 2, 2012. www.cahighspeedrail.ca.gov.
45. Ibid.
46. S.L Grassie, "Rail corrugation: characteristics, causes, and treatments ," Journal of Rail and Rapid Transit , 223, no. 6 (2009): 581-596, <http://www.mendeley.com/research/rail-corrugation-characteristics-causes-treatments/> (accessed February 2, 2012).
47. American Public Transportation Association, Economic Development Research Group. "Job Impacts of Spending on Public Transportation: An Update," White Paper (April 29, 2009) www.apta.com/gap/policyresearch/Documents/jobs_impact.pdf (accessed February 2, 2012).
48. EDR Group and Siemens. "Economic Impact of High-Speed Rail on Cities and Their Metropolitan Areas", Conference Paper, (US Conference of Mayors, Boston, June 2010). www.edrgroup.com/attachments/-01_Forbis-PRNewswire-HSR.pdf (accessed February 2, 2012).
49. U.S. Department of Labor, Bureau of Labor Statistics. "Career Guide to Industries, 2010-11 Edition," Accessed October 13, 2011. <http://www.bls.gov/oco/cg/>.
50. U.S. Department of Labor, Bureau of Labor Statistics. "Occupational Outlook Handbook, 2010-11 Edition," Accessed October 13, 2011. <http://www.bls.gov/oco/ocos027.htm>.
51. U.S. Department of Labor, Bureau of Labor Statistics, "Career Guide to Industries", op cit.
52. O*NET Construction Labor Survey, Summary Report for: 47-2061.00 - Construction Laborers, <http://www.onetonline.org/link/summary/47-2061.00> (accessed Feb 2, 2012).
53. Parsons Brinkerhoff, "California High Speed Rail Project: Technical Memorandum: Cost Changes from 2009 Report to 2012 Business Plan Capital Cost Estimates",

- October, 2011, Accessed Feb 2, 2012, <http://www.cahighspeedrail.ca.gov/assets/0/152/302/321/02fa2469-ef00-4eb0-ac78-74edff7b4fc3.pdf>.
54. California Community Colleges Registry. "Registry Plus." www.cccregistry.org/ (accessed November 15, 2011).
 55. Canadian National Railway. "Careers- our offer to you." Accessed March 5, 2011 <http://www.cn.ca/en/careers-offer.htm>.
 56. Modoc Railroad Academy. "Welcome to Modoc Railroad Academy," Accessed February 7, 2011. http://www.modocrailroadacademy.com/mra_main.html.
 57. Railroad Training Services. "Railroad Trainers and Consultants- Meet Our Training Staff." Last modified 2010. Accessed February 8, 2012. <http://railroadtrainingservices.com/staff.html>.
 58. California Apprenticeship Coordinators Association. "Regional Chapters." Accessed February 2, 2012. www.calapprenticeship.org/regional_chapters.php.
 59. National Surface Transportation Policy and Revenue Study Commission-Section 1909. "The U.S. Freight Rail System: Structure, Finance, and Emerging Issues", January 11, 2007. Accessed May 3, 2011. http://transportationfortomorrow.com/final_report/volume_3_html/special_issues_analyses/paper2b5c.htm?name=8c_01.
 60. Kent Riffey and Tony Daniels, (Chief Engineer and Program Director), Presented at Project Implementation and Phasing Workshop, August 06, 2009.
 61. Schiedel, Jason and Thomas R. Gibson. AECOM, "How To Develop the Next Generation of Signal Maintainers And Engineers." Accessed January 10, 2011. <http://trid.trb.org/view.aspx?id=1085164>.
 62. Christopher Barkan, professor, University of Illinois- Urbana Champagne, interviewed by Katherine Estrada, February 10, 2011.
 63. U.S. News and World Report. "World's Best Universities: Civil Engineering." Accessed February 2, 2012. <http://www.usnews.com/education/worlds-best-universities-rankings/best-universities-civil-engineering>.
 64. California State Polytechnic University, Pomona. "California Department of Transportation (Caltrans) awarded Cal Poly Pomona a \$1 million, 3-year contract." Accessed February 10, 2011. <http://www.csupomona.edu/~ce/>.
 65. U.S. Department of Transportation. "Federal Railroad Administration: FY 2011 Congressional Budget Submission, FRA," Accessed January 3, 2011. www.dot.gov/budget/2011/budgetestimates/rita.pdf.
 66. U.S. Department of Transportation. "Federal Railroad Administration: FY 2011 Congressional Budget Submission, FHWA," Accessed January 3, 2011. www.dot.gov/budget/2011/budgetestimates/fhwa.pdf.
 67. Ibid, p. V-2.

-
68. U.S. Department of Transportation, Research and Innovative Technology Administration. "John A. Volpe National Transportation Systems Center," Accessed January 10, 2011. <http://www.volpe.dot.gov/rail/index.html>.
 69. U.S. Department of Transportation, Federal Railroad Administration. "High-Speed Passenger Rail Safety Strategy," 2009. Accessed January 4, 2011. www.fra.dot.gov/downloads/safety/HSRSafetyStrategy110609.pdf.
 70. Transportation Resource Board. "Cooperative Research Programs Division," Accessed January 11, 2011 <http://www.trb.org/AboutTRB/Public/AboutCooperativeResearchPrograms.aspx>.
 71. Grants.gov. "Research and Demonstration Projects Supporting the Development of High Speed and Intercity Passenger Rail Service; Current Awards and Interested Vendor List." Accessed October 26, 2011. <http://www07.grants.gov/search/search.do?oppld=56195&mode=VIEW>.
 72. AREMA. "Technical Committees: Committee 24- Education and Training." Accessed February 8, 2011. <http://www.arema.org/committees/cf/c23.cfm>.
 73. Texas Transportation Institute. "AAR Affiliated Laboratories." Accessed February 15, 2011. http://tti.tamu.edu/group/rail/aar_lab/.
 74. University of Illinois. "Railroad Engineering Program Overview." Accessed January 15, 2011. <http://ict.illinois.edu/railroad/CEE/overview.asp>.
 75. University of Illinois. "High Speed Rail Engineering." Accessed January 15, 2011. <http://ict.illinois.edu/railroad/CEE/cee598hsr.asp>.
 76. Midwest High Speed Rail Association. "Governor Quinn Announces Partnership with University of Illinois to Study 220-mph Rail Service", June 2, 2011. <http://www.midwesthsr.org/governor-quinn-announces-partnership-with-university-of-illinois-to-study-220-mph-rail-service> (accessed June 6, 2011).
 77. Stuttgart-Ulm Rail Project. "Leiter (m/w) Arbeitsgebiet Technisches Projektmanagement," Accessed January 15, 2011. <http://www.bahnprojekt-stuttgart-ulm.de/en-gb/default.aspx>.
 78. Rose, Jerry G., Teixeira, Paulo F., and Nathan E. Ridgeway. "Utilization of Asphalt/ Bituminous Layers and Coatings in Railway Trackbeds- A Compendium of International Applications" (2010). www.engr.uky.edu/~jrose/papers/JRC_2010_International.pdf (Accessed February 10, 2011).
 79. University of Kentucky. "Dr. Jerry G. Rose, PE." Accessed February 10, 2011. <http://www.engr.uky.edu/~jrose/index432.html>.
 80. Michigan State University. "Railway Management Programs." Accessed October 20, 2010. <http://www.raileducation.com/>.
 81. Parsons Brinkerhoff, "California High Speed Rail Project: California High-Speed Rail 2012 Business Plan", November, 2011, Accessed Feb 2, 2012.

-
82. University of Wisconsin-Madison. "Department of Engineering: Professional Development." Accessed January 15, 2011. <http://epdweb.engr.wisc.edu/railroad-engineering-courses.lasso>.
 83. Ibid.
 84. David Clarke, professor, University of Tennessee- Knoxville, interviewed by Katherine Estrada, February 20, 2011.
 85. University of Tennessee- Knoxville. "UT Engineering Delegation Visits Beijing, Discusses Collaborations," Tennessee Today, October 7, 2010. http://www.utk.edu/tntoday/2010/10/07/engineering-delegation-visits-beijing/?utm_source=tntodayandutm_medium=emailandutm_campaign=2010-10-08 (Accessed November 10, 2010).
 86. Vantuono, William C. "High speed rail: a huge opportunity", Railway Age, October 2009.
 87. Danish Technological Institute, CAS, and First Lloyds Register Rail Europe. "Rail training 2020: Training needs and offers in the European railway area the next 10 - 15 years," (2007), ec.europa.eu/transport/rail/studies/doc/2007_rail_training_2020.pdf (accessed February 2, 2012).
 88. European Commission. "High speed rail system", October 30, 2010. http://ec.europa.eu/transport/rail/interoperability/high_speed_en.htm (accessed November 20, 2010).
 89. SNCF. "Career Opportunities: Job Profiles." Accessed January 15, 2011. http://www.sncf.com/en_EN/flash/#/CH0003/BR0784/.
 90. Amtrak. "Amtrack Career Opportunities: Passenger Engineering Trainee." Accessed on February 5, 2011. www.amtrak.com/careers.
 91. Union Pacific. "Co-op/Internship." Accessed March 14, 2011. http://www.unionpacific.jobs/careers/explore/college/intern_coop.shtml.
 92. Amtrak. "Professional Development Program." Accessed March 10, 2011. <http://www.amtrak.com/servlet/ContentServer/Page/1241267278317/es>.
 93. Canadian National Railway, op cit.
 94. Yang, Rui. "Toward Massification: Higher Education Development in the People's Republic of China Since 1949" J.C. Smart (ed.), Higher Education: Handbook of Theory and Research, (2005) Vol. XIX, 311–374.
 95. Shepherd, Jessica. "A very Chinese revolution," The Guardian, December 4, 2007 <http://www.guardian.co.uk/education/2007/dec/04/schoolsworldwide.schools> (accessed January 13, 2011).
 96. Southwest Jiaotong University. "Professional training plans for IT business and transportation," Accessed September 10, 2010. <http://www.at0086.com/SJTU/College-list.aspx#>.

97. The National Academy of Sciences. "Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future," October 20, 2005.
98. Chinese Academy of Railway Sciences. "About Chinese Academy of Railway Sciences." Accessed June 30, 2010. cars.rails.com.cn/2j/about/index.asp.
99. RSSB. "More about RSSB's capabilities." Accessed June 30, 2011. <http://www.rssb.co.uk/AboutUs/Pages/MoreAboutRSSBsCapabilities.aspx>.
100. Network Rail. "Our company structure." Accessed June 30, 2011. <http://www.networkrail.co.uk/aspx/711.aspx>.
101. Rail Research UK Association. "A partnership between Britain's rail industry and UK universities." Accessed January 8, 2011. <http://www.rruka.org.uk/>.
102. University of Southampton. "Transportation group research division." Accessed January 10, 2011. <http://www.civil.soton.ac.uk/research/divisions/divlist.asp?ResearchGroupID=4>.
103. Quinn et al. "A full-scale experimental and modeling study of ballast flight under high-speed trains," *Journal of Rail and Rapid Transit*, vol. 224 no. 2 (March 1, 2010): 61-74, <http://pif.sagepub.com/content/224/2/61.refs> (accessed January 9, 2011).
104. Danish Technological Institute, CAS, and First Lloyds Register Rail Europe, op cit.
105. Maurant, Andrew. "High speed rail links," *The Guardian*, January 4, 2011, <http://www.guardian.co.uk/education/2011/jan/04/railway-engineering-skills-academy-business-secretary> (accessed January 10, 2011).
106. Grants.gov, op cit.
107. University of Wisconsin. "Central Japan Railway Company (CJR) – UW-Madison Internship Program. Summer 2010." Accessed February 20, 2011. international.wisc.edu/blog/wp-content/uploads/2010/02/CJR20101.pdf.
108. Ho, Jessie and Jackie Lin. "High speed rail commences operations," *Taipei Times*, Jan 6, 2007. <http://www.taipeitimes.com/News/front/archives/2007/01/06/2003343562> (accessed June 15, 2011).
109. National Taiwan University, op cit.
110. Korea Railroad Research Institute. "History." Accessed March 1, 2011. http://www.krri.re.kr/krri_2008/institute/history/index.html.
111. Korea Railroad Research Institute. "Organizational Chart." Accessed March 2, 2011. http://www.krri.re.kr/krri_2008/institute/Organization/index.html.
112. Hughes, Murray. "Koreans start to test 350km/h KHST", *Railway Gazette*, October 1, 2002, <http://www.railwaygazette.com/nc/news/single-view/view/koreans-start-to-test-350nbspkmh-khst.html> (accessed: February 20, 2011).

-
113. UK Trade and Investment. "Korea Railroad Research Institute." Date modified: June 3, 2010. Accessed February 21, 2011. <http://212.137.70.163/uktihome/media/item/110423.html>.
 114. Danish Technological Institute, CAS, and First Lloyds Register Rail Europe, op cit.
 115. Ibid, p 13.
 116. Ibid, p 14.
 117. Ibid, p 25.
 118. Ibid, p 24.
 119. DeutscheBahn. "Sustainability in the DB Group: Responsibility for the Future." Date modified: 2009. Accessed June 30, 2010. www.deutschebahn.com.
 120. Samuel, A. 'ScotRail Recruits New Modern Apprentices', March 7, 2011. <http://www.rail.co/2011/03/07/scotrail-recruits-new-modern-apprentices/> (Accessed March 20, 2011).
 121. California State Polytechnic University, Pomona. "MSCE Program - Transportation Engineering Emphasis." Accessed March 15, 2011. <http://www.csupomona.edu/~ce/MSCE/transportation.html>.
 122. California Polytechnic State University, San Luis Obispo. "MCRP/MS in Transportation Planning." Accessed March 16, 2011. <http://ceenve.calpoly.edu/programs/mstransport/>.
 123. California State University, Long Beach. "Civil Engineering and Construction Engineering Management Graduate C E Courses." Accessed September 15, 2010. http://www.csulb.edu/divisions/aa/catalog/2009-2010/coe/ce/ce_grad_courses.html.
 124. University of California, Berkeley. "Transportation Engineering." Accessed August 15, 2010. <http://www.ce.berkeley.edu/grad/degrees/requirements/trans>.
 125. Institute of Transportation Studies, Berkeley. "About ITS." Accessed April 6, 2011. <http://its.berkeley.edu/about>.
 126. Samer Madanat, Director, ITS Berkeley, interviewed by Katherine Estrada, February 20, 2011.
 127. University of California, Irvine. "Transportation Science Graduate Program." Accessed March 10, 2011. http://www.transci.uci.edu/program_phd.
 128. UCLA ITS. "Transportation policy and planning." Accessed March 10, 2011. <http://www.its.ucla.edu/academics/courses.cfm>.
 129. University of California, Davis ITS. "China center for energy and transportation." Accessed March 10, 2011. <http://chinacenter.ucdavis.edu/activity.html>.
 130. Wong, Hung Leung. METRANS, 'Analysis of Vibrations and Infrastructure Deterioration Caused by High-Speed Rail Transit', December 2005.

-
131. METRANS Transportation Center. "Research." Accessed August 21, 2010. <http://www.metrans.org/research/2001/01-02.htm>.
 132. California State University. "Education Access and Outcomes: Student Outcomes/ Degrees Conferred, CSU", p 262, Accessed Feb 2,2012. http://www.calstate.edu/as/stat_abstract/stat0506/pdf/k_5b0506.pdf.
 133. California State University. Statistical Summary of Students and Staff University of California, Fall 2008, <http://www.ucop.edu/ucophome/uwnews/stat/>.
 134. California State Polytechnic University, Pomona. "Cal Poly Pomona Exchange Program." Accessed February 2, 2012. http://www.csupomona.edu/~international/study_abroad/exchange.shtml.
 135. Miller, John B., Garvin, Michael J., Ibbs, C. William , and Stephen E. Mahoney. "Toward a New Paradigm: Simultaneous Use of Multiple Project Delivery Methods," Journal of Management in Engineering Vol 16. 58. (2000).
 136. Ibid.
 137. Miller, John B. "Engineering Systems Integration for Civil Infrastructure Projects," Journal of Management in Engineering Vol 13. 5. (1997): 61-69.
 138. U.S. Government Accountability Office, Amtrak's Northeast Corridor: Information on the Status and Cost of Needed Improvements , GAO/RCED-95-151BR (Washington DC: GAO, April 1995), p. 24.
 139. San Francisco County Transportation Authority. "San Francisco/Silicon Valley Corridor Investment Strategy." Accessed June 2009. www.mtc.ca.gov/rail/HSR_PeninsulaInvest_brief_6-24-09.pdf.
 140. Sarah L. Catz, Director, Center for Urban Infrastructure Adam Christian, Center for Urban Infrastructure High-Speed Rail in Southern California, Institute Of Transportation Studies, interviewed by Paul Hernandez, Summer 2010.
 141. American Public Transportation Association, Economic Development Research, op cit.
 142. Ibid.
 143. Ibid.
 144. Ibid.
 145. Tony Daniels, Program Manager, California High-Speed Rail Authority, Interviewed by Paul Hernandez and Stanley Feinsod, August 10, 2010.
 146. American Public Transportation Association, Economic Development Research, op cit.
 147. Ibid.
 148. California High-Speed Rail Authority. "Draft 2012 Business Plan." Accessed February 2, 2012. http://www.cahighspeedrail.ca.gov/Business_Plan_reports.aspx.
-

-
149. Peninsula Rail Program. "California's High-Speed Train Project, January 2010 Update: A Look Back and a Look Ahead." Accessed February 2, 2012.
 150. Tony Daniels, Program Manager, California High-Speed Rail Authority, Interviewed by Paul Hernandez and Stanley Feinsod, August 10, 2010.
 151. Bivens, Josh. "Updated Employment Multipliers for the U.S. Economy (2003)." Accessed February 2, 2012. www.epi.org/page/-/old/workingpapers/epi_wp_268.pdf.
 152. American Public Transportation Association, Economic Development Research, op cit.
 153. California High-Speed Rail Authority. "2009 Business Plan, Report To Legislature" Accessed February 2, 2012. http://www.cahighspeedrail.ca.gov/Business_Plan_reports.aspx.
 154. California High-Speed Rail Authority, Business Plan, op cit.
 155. Project Management Knowledge, The Ultimate Resource for Project Managers. "Bottom-up Estimating [Technique]," Accessed February 2, 2012. <http://project-management-knowledge.com/definitions/b/bottom-up-estimating-technique/>.
 156. Parsons Brinkerhoff. "California High Speed Rail Project: Technical Memorandum: Capital Cost Estimating Methodology for the 15% Design Level TM 1.1.19." Accessed February 2, 2012. www.cahighspeedrail.ca.gov.
 157. California High-Speed Rail Authority. "California High Speed Train Creates Jobs." Prepared May 2010. Accessed February 2, 2012. <http://www.cahighspeedrail.ca.gov/assets/0/152/159/0150b8aa-a61b-4aeb-9c18-6223d8fe429f.pdf>.
 158. Tony Daniels, Program Manager, California High-Speed Rail Authority, Interviewed by Paul Hernandez and Stanley Feinsod, August 10, 2010.
 159. California High-Speed Rail Authority. "2011 Report to the Legislature." Accessed February 2, 2012. http://www.cahighspeedrail.ca.gov/Business_Plan_reports.aspx.
 160. Tony Daniels, Program Manager, California High-Speed Rail Authority, Interviewed by Paul Hernandez and Stanley Feinsod, August 10, 2010.
 161. U.S. Department of Labor, U.S. Bureau of Labor Statistics. "Education and training measurements by detailed occupation, 2008-2009." accessed February 2, 2012, http://www.bls.gov/emp/ep_table_111.htm.
 162. O*NET Online, U.S. Department of Labor, Employment & Training Administration, O*NET Survey of Construction Laborers, Based on Percentage of Respondents, and Education Level Required, Accessed February 2, 2012, <http://www.onetonline.org/link/summary/47-2061.00>.
 163. U.S. Department of Labor, U.S. Bureau of Labor Statistics, op cit.
 164. Hayek, F.A. "The Ricardo Effect." *Economica*. 9. no. 34 (1942): 127-152.

BIBLIOGRAPHY

- American Public Transportation Association, Economic Development Research Group. "Job Impacts of Spending on Public Transportation: An Update," White Paper (April 29, 2009) www.apta.com/gap/policyresearch/Documents/jobs_impact.pdf (accessed February 2, 2012).
- Amtrak. "Amtrack Career Opportunities: Passenger Engineering Trainee." www.amtrak.com/careers (accessed on February 5, 2011).
- AREMA. "Technical Committees: Committee 24- Education and Training." <http://www.arena.org/committees/cf/c23.cfm> (accessed February 8, 2011).
- Bivens, Josh. "Updated Employment Multipliers for the U.S. Economy (2003)." www.epi.org/page/-/old/workingpapers/epi_wp_268.pdf (accessed February 2, 2012).
- Bousquet, Paul. United States Department of Transportation, Research and Innovative Technologies Administration, Volpe National Transportation Systems Center. "Use of New Technology for Highway Rail Intersections and Train Control." Working Paper. (Western Regional Safety Grade-Crossing, Training Conference, Costa Mesa, CA, May 3, 2005).
- California Apprenticeship Coordinators Association. "Regional Chapters." www.calapprenticeship.org/regional_chapters.php (accessed February 2, 2012).
- California Community Colleges Registry. "Registry Plus." www.cccregistry.org/ (accessed November 15, 2011).
- California High-Speed Rail Authority. "Project Scope and Vision." Last modified 2010. http://www.cahighspeedrail.ca.gov/project_vision.aspx (accessed February 2, 2012).
- _____. "2011 Report to the Legislature." http://www.cahighspeedrail.ca.gov/Business_Plan_reports.aspx (accessed February 2, 2012).
- _____. "California High Speed Train Creates Jobs." <http://www.cahighspeedrail.ca.gov/assets/0/152/159/0150b8aa-a61b-4aeb-9c18-6223d8fe429f.pdf> (accessed February 2, 2012).
- _____. "Draft 2012 Business Plan." http://www.cahighspeedrail.ca.gov/Business_Plan_reports.aspx (accessed February 2, 2012).
- California Polytechnic State University, San Luis Obispo. "MCRP/MS in Transportation Planning." <http://ceenve.calpoly.edu/programs/mstransport/> (accessed March 16, 2011).

- California State Polytechnic University, Pomona. "MSCE Program - Transportation Engineering Emphasis." <http://www.csupomona.edu/~ce/MSCE/transportation.html> (accessed March 15, 2011).
- _____. "California Department of Transportation (Caltrans) awarded Cal Poly Pomona a \$1 million, 3-year contract." <http://www.csupomona.edu/~ce/> (accessed February 10, 2011).
- _____. "Cal Poly Pomona Exchange Program." http://www.csupomona.edu/~international/study_abroad/exchange.shtml (accessed February 2, 2011).
- California State University. "Education Access and Outcomes: Student Outcomes/ Degrees Conferred, CSU." http://www.calstate.edu/as/stat_abstract/stat0506/pdf/k_5b0506.pdf (accessed February 2, 2012).
- California State University, Long Beach. "Civil Engineering and Construction Engineering Management Graduate C E Courses." http://www.csulb.edu/divisions/aa/catalog/2009-2010/coe/ce/ce_grad_courses.html (accessed September 15, 2010).
- Canadian National Railway. "Careers- our offer to you." <http://www.cn.ca/en/careers-offer.htm> (accessed March 5, 2011).
- Chinese Academy of Railway Sciences. "About Chinese Academy of Railway Sciences." cars.rails.com.cn/ (accessed June 30, 2010).
- Chuang, Michael Y., and William H. A. Johnson. "'Hop on board': The importation and future development of high-speed rail (HSR) in China," *Journal of Technology Management in China*, 6, no. 3 (2011): 232-41.
- Danish Technological Institute, CAS, and First Lloyds Register Rail Europe. "Rail training 2020: Training needs and offers in the European railway area the next 10 - 15 years," (2007), ec.europa.eu/transport/rail/studies/doc/2007_rail_training_2020.pdf (accessed February 2, 2012).
- Degrande, G. "Free field vibrations during the passage of a high speed train: validation of a numerical model by means of experimental results," (Paper presented at *Proceedings of the 13th ASCE Engineering Mechanics Division Specialty Conference*, Baltimore, MD, 1999).
- DeutscheBahn. "Sustainability in the DB Group: Responsibility for the Future." Date modified: 2009. www.deutschebahn.com (accessed June 30, 2010).
- EDR Group and Siemens. "Economic Impact of High-Speed Rail on Cities and Their Metropolitan Areas", Conference Paper, (US Conference of Mayors, Boston, June 2010). www.edrgroup.com/attachments/-01_Forbis-PRNewswire-HSR.pdf (accessed February 2, 2012).

- ENSCO. "Autonomous Track Geometry Measurement System (ATGMS)." http://www.ensco.com/userfiles/file/Products_Services_PDF/07_Rail/Track-Inspection-Systems/090091-Rail-Autonomous-Track-Geometry-Measurement-System-ENSCO.pdf (accessed February 2, 2012).
- European Commission. "High speed rail system", (October 30, 2010). http://ec.europa.eu/transport/rail/interoperability/high_speed_en.htm (accessed November 20, 2010).
- Federal Business Opportunities. "Research and Demonstration Projects Supporting the Development of High Speed and Intercity Passenger Rail Service," (July 28, 2010). https://www.fbo.gov/index?s=opportunity&mode=form&id=969909348e74d211d3eb4e2c9753f3f7&tab=core&_cview=1 (accessed February 2, 2012).
- Grants.gov. "Research and Demonstration Projects Supporting the Development of High Speed and Intercity Passenger Rail Service; Current Awards and Interested Vendor List." <http://www07.grants.gov/search/search.do?oppld=56195&mode=VIEW> (accessed October 26, 2011).
- Hayek, F.A. "The Ricardo Effect." *Economica*. 9. no. 34 (1942): 127-152.
- Ho, Jessie and Jackie Lin. "High speed rail commences operations," *Taipei Times*, January 6, 2007. <http://www.taipeitimes.com/News/front/archives/2007/01/06/2003343562> (accessed February 2, 2012).
- Hughes, Murray. "Koreans start to test 350km/h KHST", *Railway Gazette*, October 1, 2002, <http://www.railwaygazette.com/nc/news/single-view/view/koreans-start-to-test-350nbpskmh-khst.html> (accessed: February 20, 2011).
- Institute of Transportation Studies, Berkeley. "About ITS." <http://its.berkeley.edu/about> (accessed April 6, 2011).
- International Union of Railways. "UIC Leaflet 791-1 RI: Maintenance guidelines for overhead contact lines", (2004). www.uic.org/com/IMG/pdf/UIC_Leaflet_791-2.pdf (accessed February 2, 2012).
- K. E. Haynes, C. Karlsson, and U. Blum. "The regional and urban effects of high-speed trains," *The Annals of Regional Science*, Springer, 31, no. 1 (1997): 1-20.
- Korea Railroad Research Institute. "History." http://www.krri.re.kr/krri_2008/institute/history/index.html (accessed March 1, 2011).
- _____. "Organizational Chart." http://www.krri.re.kr/krri_2008/institute/Organization/index.html (accessed March 2, 2011).

- Lombaert, G., Degrande, G., and J. Bekaert. "The influence of the train speed on vibrations due to high speed trains," *Noise And Vibration Mitigation For Rail Transportation Systems*, Vol. 99 (2008): 19-25.
- Mahendran, Anusha and Alfred Michael Dockery. "Forecasting the Workforce Needs of the Australian Rail Transport Industry (ARTI)" Conference Paper 116148 (Centre for Labour Market Research, Curtin Business School, Curtin University of Technology, October, 2008), <http://www.patrec.org/conferences/PATRECForum-Oct2008/index.php#papers> (accessed February 2, 2012).
- Mahendran, Anusha, Alfred Michael Dockery, and Fred Affleck. "A Profile of Training and Skills Development in the Australian Rail Industry" Conference Paper (Curtin Business School, Curtin University of Technology, September 2007). http://www.ecosoc.org.au/files/File/TAS/ACE07/pages/ace_papers.htm (accessed February 2, 2012).
- Mahmood Fateh. Federal Railroad Administration, "On-line High-speed Rail Defect Detection – Phase III," October 2005. www.fra.dot.gov/downloads/research/rr0507.pdf (accessed February 2, 2012).
- METRANS Transportation Center. "Research." <http://www.metrans.org/research/2001/01-02.htm> (accessed August 21, 2010).
- Michigan State University. "Railway Management Programs." <http://www.raileducation.com/> (accessed October 20, 2010).
- Midwest High Speed Rail Association. "Governor Quinn Announces Partnership with University of Illinois to Study 220-mph Rail Service", June 2, 2011. <http://www.midwesthsr.org/governor-quinn-announces-partnership-with-university-of-illinois-to-study-220-mph-rail-service> (accessed June 6, 2011).
- Miller, John B. "Engineering Systems Integration for Civil Infrastructure Projects," *Journal of Management in Engineering* Vol 13. 5. (1997): 61-69.
- Miller, John B., Garvin, Michael J., Ibbs, C. William , and Stephen E. Mahoney. "Toward a New Paradigm: Simultaneous Use of Multiple Project Delivery Methods," *Journal of Management in Engineering* Vol 16. 58. (2000).
- Modoc Railroad Academy. "Welcome to Modoc Railroad Academy." http://www.modocrailroadacademy.com/mra_main.html (accessed February 7, 2011).
- Mourant, Andrew. "High speed rail links," *The Guardian*, January 4, 2011, <http://www.guardian.co.uk/education/2011/jan/04/railway-engineering-skills-academy-business-secretary> (accessed January 10, 2011).

Murakami, Jin, and Robert Cervero. "Environmental and Other Co-benefits of Developing a High Speed Rail System in California: A Prospective Vision 2010-2050," Working Paper CEPP004, (UCB Center for Environmental Policy, 2010).

National Academy of Sciences. "Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future," October 20, 2005.

National Surface Transportation Policy and Revenue Study Commission-Section 1909. "The U.S. Freight Rail System: Structure, Finance, and Emerging Issues", January 11, 2007. http://transportationfortomorrow.com/final_report/volume_3_html/special_issues_analyses/paper2b5c.htm?name=8c_01 (accessed May 3, 2011).

National Taiwan University. "Railway Technology Research Center, National Taiwan University: About RTRC," (2010).

Network Rail. "Our company structure." <http://www.networkrail.co.uk/aspx/711.aspx> (accessed June 30, 2011).

O*NET Construction Labor Survey. "Summary Report for: 47-2061.00 - Construction Laborers." <http://www.onetonline.org/link/summary/47-2061.00> (accessed February 2, 2012).

Park, Jung Ho, Chi, Heon Cheol, Seub Lim, In, Kim, Geun Young, and Jin Soo Shin. "Korea Integrated Seismic System (KISS) and Earthquake Monitoring for Korea Train eXpress (KTX)". Presentation to EGU General Assembly 2010, (May 2010): p.9850.

Parsons Brinkerhoff. "California High Speed Rail Project Technical Memorandum: Automatic Train Control: Concept of System TM 2.2.2.1." www.cahighspeedrail.ca.gov (accessed February 2, 2012).

_____. "California High Speed Rail Project: Technical Memorandum: Capital Cost Estimating Methodology for the 15% Design Level TM 1.1.19." www.cahighspeedrail.ca.gov (accessed February 2, 2012).

_____. "California High Speed Rail Project: Technical Memorandum: Cost Changes from 2009 Report to 2012 Business Plan Capital Cost Estimates", October, 2011. <http://www.cahighspeedrail.ca.gov/assets/0/152/302/321/02fa2469-ef00-4eb0-ac78-74edff7b4fc3.pdf> (accessed February 2, 2012).

_____. "California High Speed Rail Project Technical Memorandum: Overhead Contact System Requirements, TM 2.2.2.1." www.cahighspeedrail.ca.gov (accessed February 2, 2012).

_____. "California High Speed Rail Project Technical Memorandum: Structure Design Loads TM 2.2.3." www.cahighspeedrail.ca.gov (accessed February 2, 2012).

-
- _____. "California High Speed Rail Project Technical Memorandum: Summary Description of Requirements and Guidelines for Heavy Maintenance Facility (HMF), Terminal Layup/Storage and Maintenance Facilities and Right-of-Way Maintenance Facilities TM 5.3," August 2009. www.cahighspeedrail.ca.gov (accessed February 2, 2012).
- _____. "California High Speed Rail Project: Technical Memorandum: Terminal and Heavy Maintenance Facility Guidelines TM 5.1," August 2009. www.cahighspeedrail.ca.gov (accessed February 2, 2012).
- _____. "California High-Speed Rail Project Economic Impact Analysis Report," October 2011.
- _____. "California High Speed Rail Project: 2012 Business Plan", November 2011.
- Peninsula Rail Program. "California's High-Speed Train Project, January 2010 Update: A Look Back and a Look Ahead." <http://www.belmont.gov/Upload/Document/D240005456/HSRJanuary2010Update.pdf> (accessed February 2, 2012).
- Project Management Knowledge, The Ultimate Resource for Project Managers. "Bottom-up Estimating [Technique]." <http://project-management-knowledge.com/definitions/b/bottom-up-estimating-technique/> (accessed February 2, 2012).
- Quinn et al. "A full-scale experimental and modeling study of ballast flight under high-speed trains," Journal of Rail and Rapid Transit, vol. 224 no. 2 (March 1, 2010): 61-74, <http://pif.sagepub.com/content/224/2/61.refs> (accessed January 9, 2011).
- Rail Research UK Association. "A partnership between Britain's rail industry and UK universities." <http://www.rruka.org.uk/> (accessed January 8, 2011).
- Railroad Training Services. "Railroad Trainers and Consultants- Meet Our Training Staff." Last modified 2010. Accessed February 8, 2011. <http://railroadtrainingservices.com/staff.html>.
- Randolph, Sean. "Economic Benefits and Impacts in the San Francisco Bay Area," (October 2008), <http://www.bayareaeconomy.org/publications-list/> (accessed February 2, 2012).
- Rose, Jerry G., Teixeira, Paulo F., and Nathan E. Ridgeway. "Utilization of Asphalt/ Bituminous Layers and Coatings in Railway Trackbeds- A Compendium of International Applications" (2010). www.engr.uky.edu/~jrose/papers/JRC_2010_International.pdf (accessed February 10, 2011).
- RSSB. "More about RSSB's capabilities." <http://www.rssb.co.uk/AboutUs/Pages/MoreAboutRSSBsCapabilities.aspx> (accessed June 30, 2011).
-

- S.L Grassie, "Rail corrugation: characteristics, causes, and treatments ," *Journal of Rail and Rapid Transit* , 223, no. 6 (2009): 581-596, <http://www.mendeley.com/research/rail-corrugation-characteristics-causes-treatments/> (accessed February 2, 2012).
- Samuel, A. 'ScotRail Recruits New Modern Apprentices', March 7, 2011. <http://www.rail.co/2011/03/07/scotrail-recruits-new-modern-apprentices/> (accessed March 20, 2011).
- San Francisco County Transportation Authority. "San Francisco/Silicon Valley Corridor Investment Strategy." www.mtc.ca.gov/rail/HSR_PeninsulaInvest_brief_6-24-09.pdf (accessed June 2009).
- Schiedel, Jason and Thomas R. Gibson. AECOM, "How To Develop the Next Generation of Signal Maintainers And Engineers." <http://trid.trb.org/view.aspx?id=1085164> (accessed January 10, 2011).
- Shepherd, Jessica. "A very Chinese revolution," *The Guardian*, December 4, 2007 <http://www.guardian.co.uk/education/2007/dec/04/schoolsworldwide.schools> (accessed January 13, 2011).
- SNCF International, "In South Korea," May 2008, http://www.sncf-international.net/52B4F302-5132-4843-85F8-625F70C984FD/FinalDownload/DownloadId-4D1C1FC1D61CDE845D359CF9985B4D64/52B4F302-5132-4843-85F8-625F70C984FD/upl/file/FP_Coree-du-Sud_GB.pdf (accessed summer 2011).
- SNCF. "Career Opportunities: Job Profiles." http://www.sncf.com/en_EN/flash/#/CH0003/BR0784/ (accessed January 15, 2011).
- Southwest Jioatong University. "[Professional training plans for IT business and transportation]," <http://www.at0086.com/SJTU/College-list.aspx#> (accessed September 10, 2010).
- Stuttgart-Ulm Rail Project. "Leiter (m/w) Arbeitsgebiet Technisches Projektmanagement," <http://www.bahnprojekt-stuttgart-ulm.de/en-gb/default.aspx> (accessed January 15, 2011).
- Texas Transportation Institute. "AAR Affiliated Laboratories." http://tti.tamu.edu/group/rail/aar_lab/ (accessed February 15, 2011).
- Transportation Resource Board. "Cooperative Research Programs Division," <http://www.trb.org/AboutTRB/Public/AboutCooperativeResearchPrograms.aspx> (accessed January 11, 2011).

- U. S. Government Accountability Office. Report to Congressional Committees-Rail Safety: Federal Railroad Administration Should Report on Risks to the Successful Implementation of Mandated Safety Technology, (Government Accountability Office, 2010). www.gao.gov/new.items/d11133.pdf (accessed June 25, 2010).
- U.S. Department of Labor, Bureau of Labor Statistics. "Career Guide to Industries, 2010-11 Edition." <http://www.bls.gov/oco/cg/> (accessed October 13, 2011).
- _____. "Occupational Outlook Handbook, 2010-11 Edition." <http://www.bls.gov/oco/ocos027.htm> (accessed October 13, 2011).
- _____. "Education and training measurements by detailed occupation, 2008-2009." http://www.bls.gov/emp/ep_table_111.htm. (accessed February 2, 2012).
- U.S. Department of Transportation. "Federal Railroad Administration: FY 2011 Congressional Budget Submission, FHWA," www.dot.gov/budget/2011/budgetestimates/fhwa.pdf (accessed January 3, 2011).
- _____. "Federal Railroad Administration: FY 2011 Congressional Budget Submission, FRA." www.dot.gov/budget/2011/budgetestimates/rita.pdf (accessed January 3, 2011).
- _____. U.S. Department of Transportation, Federal Railroad Administration. "High-Speed Intercity Passenger Rail Program." <http://www.fra.dot.gov/rpd/passenger/2243.shtml> (accessed February 2, 2012).
- _____. "High-Speed Passenger Rail Safety Strategy," 2009. www.fra.dot.gov/downloads/safety/HSRSafetyStrategy110609.pdf (accessed January 4, 2011).
- _____. "Intelligent Railroad Systems: Positive Train Control (PTC)." <http://www.fra.dot.gov/Pages/784.shtml> (accessed February 2, 2012).
- _____. Preview Information in Cab Displays for High-Speed Locomotives: Human Factors in Railroad Operations, (Springfield, VA: National Technical Information Service, 2005). www.fra.dot.gov/downloads/rrdev/ord0412.pdf (accessed February 2, 2012).
- _____. "Railroad Safety Technology Grants," Last modified 2010. <http://www.fra.dot.gov/Pages/485.shtml> (accessed February 2, 2012).
- _____. Federal Railroad Safety Enhancement Act of 1999, <http://testimony.ost.dot.gov/final/secfra.htm> (accessed February 2, 2012).
- U.S. Department of Transportation, Federal Transit Administration. *Status of the Nation's Highways, Bridges and Transit: Conditions and Performance* (Washington, DC: Biennial Issues, 2008), tables 3-35 and 3-36. <http://www.fhwa.dot.gov/pubstats.html> (Accessed June 25, 2010).

- U.S. Department of Transportation, Office of Public Affairs. "U.S. Transportation Secretary La Hood And Illinois Officials Break Ground On Chicago High-Speed Rail Project Will Reduce Delays And Create Nearly 1,500 Jobs," Last modified October 10, 2011. www.dot.gov/affairs/2011/fra3111.html (accessed February 2, 2012).
- U.S. Department of Transportation, Research and Innovative Technology Administration. "John A. Volpe National Transportation Systems Center," <http://www.volpe.dot.gov/rail/index.html> (accessed January 10, 2011).
- U.S. Government Accountability Office, Amtrak's Northeast Corridor: Information on the Status and Cost of Needed Improvements , GAO/RCED-95-151BR (Washington DC: GAO, April 1995), p. 24.
- U.S. Government Printing Office. "49 CFR 661.21-State Buy America Provisions." <http://www.gpo.gov/fdsys/> (accessed February 2, 2012).
- U.S. News and World Report. "World's Best Universities: Civil Engineering." <http://www.usnews.com/education/worlds-best-universities-rankings/best-universities-civil-engineering> (accessed February 2, 2012).
- UCLA ITS. "Transportation policy and planning." <http://www.its.ucla.edu/academics/courses.cfm> (accessed March 10, 2011).
- UK Trade and Investment. "Korea Railroad Research Institute." Date modified: June 3, 2010. <http://212.137.70.163/uktihome/media/item/110423.html> (accessed February 21, 2011).
- Union Pacific. "Co-op/Internship." http://www.unionpacific.jobs/careers/explore/college/intern_coop.shtml (accessed March 14, 2011).
- University of California, Berkeley. "Transportation Engineering." <http://www.ce.berkeley.edu/grad/degrees/requirements/trans> (accessed August 15, 2010).
- University of California, Davis ITS. "China center for energy and transportation." <http://chinacenter.ucdavis.edu/activity.html> (accessed March 10, 2011).
- University of California, Irvine. "Transportation Science Graduate Program." http://www.transci.uci.edu/program_phd (accessed March 10, 2011).
- University of Illinois. "High Speed Rail Engineering." <http://ict.illinois.edu/railroad/CEE/cee598hsr.asp> (accessed January 15, 2011).
- _____. "Railroad Engineering Program Overview." <http://ict.illinois.edu/railroad/CEE/overview.asp> (accessed January 15, 2011).

- University of Kentucky. "Dr. Jerry G. Rose, PE." <http://www.engr.uky.edu/~jrose/index432.html> (accessed February 10, 2011).
- University of Southampton. "Transportation group research division." <http://www.civil.soton.ac.uk/research/divisions/divlist.asp?ResearchGroupID=4> (accessed January 10, 2011).
- University of Tennessee- Knoxville. "UT Engineering Delegation Visits Beijing, Discusses Collaborations," Tennessee Today, October 7, 2010. http://www.utk.edu/tntoday/2010/10/07/engineering-delegation-visits-beijing/?utm_source=tntodayandutm_medium=emailandutm_campaign=2010-10-08 (accessed November 10, 2010).
- University of Wisconsin. "Central Japan Railway Company (CJR) – UW-Madison Internship Program Summer 2010." international.wisc.edu/blog/wp-content/uploads/2010/02/CJR20101.pdf (accessed February 20, 2011).
- _____. "Department of Engineering: Professional Development." <http://epdweb.engr.wisc.edu/railroad-engineering-courses.lasso> (accessed January 15, 2011).
- Vantuono, William C. "High speed rail: a huge opportunity", *Railway Age*, October 2009.
- Viktor Krylov, *Noise and vibration from high-speed trains*, (London: Thomas Telford Publishing, 2001).
- Wang, Lan. China Academy of Railway Sciences, "Railway Research and Technology in China Today." globalview.uic.org/docs/meeting_dec06/7_wang_cars.pdf (accessed February 2, 2012).
- Wong, Hung Leung. METTRANS, "Analysis of Vibrations and Infrastructure Deterioration Caused by High-Speed Rail Transit", December 2005.
- Yang, Rui. "Toward Massification: Higher Education Development in the People's Republic of China Since 1949" J.C. Smart (ed.), *Higher Education: Handbook of Theory and Research*, (2005) Vol. XIX, 311–374.
- Yang, Y.B. *Wave Propagation For Train-Induced Vibrations - A Finite/Infinite Element Approach*, (eBook, World Scientific Publishing Co., 2009). <http://www.worldscibooks.com/engineering/7062.html> (accessed February 2, 2012).
- Yu, Michelle. "China to slow down High Speed Rails," *Epoch Times*, May 1, 2011, <http://www.theepochtimes.com/n2/china-news/china-to-slow-down-high-speed-rails-55643.html> (accessed February 2, 2012).
- Zhang, Jie and Pan Yong. "Research on Exterior Noise Source Identification of High Speed Trains," Conference Paper, (Key Laboratory of Traffic Safety on Track, Central South University, 2011).

ABBREVIATIONS AND ACRONYMS

AAR	Association of American Railroads
AASTHO	American Association of State Highway and Transportation Officials
APTA	American Public Transportation Association
AREMA	American Railway Engineering and Maintenance-of-Way Association
ATC	Automatic Train Control
CARS	China Academy of Railway Sciences
CEQA	California Environmental Quality Act
CHSR	California High-Speed Rail
CHSRA	California High-Speed Rail Authority
CITT	Center for International Trade and Transportation
CN	Canadian National Railway
CPP	California State Polytechnic University, Pomona
CPSLO	California State Polytechnic University, San Luis Obispo
CSU	California State University
DBOM	Design, Build, Operations, and Maintenance
EIR	Environmental Impact Report
EIS	Environmental Impact Statement
FHWA	Federal Highway Administration
FRA	Federal Railroad Administration
GAO	Government Accountability Office
GIS	Geographic Information Systems
HSR	High-Speed Rail
IDEA	Innovations Deserving Exploratory Analysis
ITE	Institute of Transportation Engineers
ITS	Institute of Transportation Studies
JR	Japan Railways
KRRI	Korea Railroad Research Institute

KTX	Korea Train Express
MSU	Michigan State University
MTU	Michigan Technological University
NEPA	National Environmental Policy Act
OCL	Overhead Catenary Lines
PTC	Positive Train Control
RailTEC	Rail Transportation and Engineering Center
RCRP	Rail Cooperative Research Program
REES	Railroad Engineering Educational Symposium
RITA	Research and Innovation Technology Administration
SNCF	National Corporation of French Railways
THSRC	Taiwan High Speed Rail Corporation
TRB	Transportation Research Board
UCI	University of California, Irvine
UCLA	University of California, Los Angeles
UIUC	University of Illinois at Urbana-Champaign
UP	Union Pacific Railroad
USC	University of Southern California
USDOT	U.S. Department of Transportation
UTC	University Transportation Centers
UCTC	University of California Transportation Center

ABOUT THE AUTHORS

PETER J. HAAS, PhD

Peter J. Haas is a Professor in the Department of Political Science at San José State University and also serves as Education Director for the Mineta Transportation Institute. The author of numerous scholarly and professional articles, he earned a PhD in Political Science (concentration in Public Policy and Public Administration) from the University of North Carolina at Chapel Hill in 1985. A former director of the SJSU Master of Public Administration program, he also has consulted at every level of government and for various nonprofit agencies. Dr. Haas has authored and co-authored numerous reports and other publications covering transportation and is co-author of the text *Applied Policy Research: Concepts and Cases*. In 2003, he received a Senior Specialist grant from the Fulbright Foundation to teach and study in Latvia.

PAUL HERNANDEZ, MP IA

Paul Hernandez is a Research Associate with Mineta Transportation Institute. He holds a Master of Pacific International Affairs degree from the Graduate School of International Relations and Pacific Studies (IR/PS), from the University of California, San Diego, with focus on transportation policy and analysis. He also holds a Politics BA from University of California, Santa Cruz. His research interests include state, national, and international high-speed rail systems, as well as the emerging transportation infrastructure and technology initiatives in California. He is currently working as a consultant on FRA high-speed rail projects, and advising transportation technology start-up firms.

KATHERINE ESTRADA, MPA

Katherine Estrada recently earned her Master of Public Administration degree from San José State University. She previously served as a research assistant while earning her undergraduate degree in Political Science from the University of California, Los Angeles. Currently employed by the City of San José, her research interests include transportation and land use planning.

PEER REVIEW

San José State University, of the California State University system, and the MTI Board of Trustees have agreed upon a peer review process required for all research published by MTI. The purpose of the review process is to ensure that the results presented are based upon a professionally acceptable research protocol.

Research projects begin with the approval of a scope of work by the sponsoring entities, with in-process reviews by the MTI Research Director and the Research Associated Policy Oversight Committee (RAPOC). Review of the draft research product is conducted by the Research Committee of the Board of Trustees and may include invited critiques from other professionals in the subject field. The review is based on the professional propriety of the research methodology.

MTI FOUNDER

Hon. Norman Y. Mineta

MTI BOARD OF TRUSTEES

Honorary Chairman

John L. Mica (Ex-Officio)

Chair
House Transportation and
Infrastructure Committee
House of Representatives

Honorary Co-Chair, Honorable

Nick Rahall (Ex-Officio)

Vice Chairman
House Transportation and
Infrastructure Committee
House of Representatives

Chair, Mortimer Downey

(TE 2013)

Senior Advisor
PB Consult Inc.

Vice Chair, Steve Heminger

(TE 2013)

Executive Director
Metropolitan Transportation
Commission

Executive Director

Rod Diridon* (TE 2011)

Mineta Transportation Institute

Thomas E. Barron (TE 2013)

President
Parsons Transportation Group

Ignacio Barron de Angoiti

(Ex-Officio)

Director Passenger and High Speed
Department
International Union of Railways
(UIC)

Joseph Boardman (Ex-Officio)

Chief Executive Officer
Amtrak

Donald H. Camph (TE 2012)

President
California Institute for Technology
Exchange

Anne P. Canby (TE 2011)

President
Surface Transportation Policy Project

Julie Cunningham (TE 2013)

Executive Director/CEO
Conference of Minority
Transportation Officials

William Dorey (TE 2012)

President/CEO
Granite Construction Inc.

Malcolm Dougherty

(Ex-Officio)

Acting Director
California Department of
Transportation

Nuria I. Fernandez (TE 2013)

Senior Vice President
Major Programs Group CHRMHill

Rose Guilbault (TE 2012)

Vice President
American Automobile Association

Ed Hamberger (Ex-Officio)

President/CEO
Association of American Railroads

John Horsley

(Ex-Officio)*

Executive Director
American Association of State
Highway and Transportation Officials
(AASHTO)

Will Kempton (TE 2012)

CEO
Orange County Transportation
Authority

Michael P. Melaniphy

(Ex-Officio)

President & CEO
American Public Transportation
Association (APTA)

William Millar* (Ex-Officio)

President
American Public Transportation
Association (APTA)

Norman Y. Mineta (Ex-Officio)

Vice Chairman
Hill & Knowlton
Secretary of Transportation (ret.)

Stephanie L. Pinson (TE 2013)

President/COO
Gilbert Tweed Associates, Inc.

David Steele (Ex-Officio)

Dean, College of Business
San José State University

Paul Toliver* (TE 2013)

President
New Age Industries

Michael S. Townes (TE 2011)

President/CEO (ret.)
Transportation District Commission of
Hampton Roads

David L. Turney* (TE 2012)

Chairman, President & CEO
Digital Recorders, Inc.

Edward Wytkind (Ex-Officio)

President
Transportation Trades Department,
AFL-CIO

** Honorary
* Chair
^ Vice Chair
Past Chair

Directors

Hon. Rod Diridon, Sr.

Executive Director

Karen E. Philbrick, PhD

Research Director

Peter Haas, PhD

Education Director

Donna Maurillo

Communications Director

Brian Michael Jenkins

National Transportation Security Center

Asha Weinstein Agrawal, PhD

National Transportation Finance Center

Research Associates Policy Oversight Committee

Asha Weinstein Agrawal, PhD

Urban and Regional Planning
San José State University

Jan Botha, PhD

Civil & Environmental Engineering
San José State University

Katherine Kao Cushing, PhD

Environmental Science
San José State University

Dave Czerwinski, PhD

Marketing and Decision Science
San José State University

Frances Edwards, PhD

Political Science
San José State University

Taeho Park, PhD

Organization and Management
San José State University

Diana Wu

Martin Luther King, Jr. Library
San José State University



MINETA
TRANSPORTATION INSTITUTE
MTI



SAN JOSÉ STATE
UNIVERSITY

Funded by U.S. Department of
Transportation and California
Department of Transportation

