TUNRAIL

TUNING TRANSATLANTIC COOPERATION IN RAIL HIGHER EDUCATION

Handbook for Rail Higher Education

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1 Executive Summary

Tuning Transatlantic Cooperation in Rail Higher Education (TUNRail) is a policy oriented project to study the demand and availability of rail higher education in the European Union (E.U.) and the United States (U.S.) and to foster transatlantic collaboration in the field. The project was conducted between September, 2009 and August, 2011 and funded through an E.U.-US Atlantis grant from the Fund for the Improvement of Postsecondary Education (FIPSE), the US Department of Education, and the Executive Agency for Education Audiovisual and Culture (EACEA), a branch of the European Commission.

The focus of TUNRail was on increasing the transparency of railway higher education programs, as well as on increasing the understanding of the synergies and differences of railway systems and higher education on both sides of the Atlantic. In essence, TUNRail developed an inventory of the current learning opportunities and competencies and compared them to demand placed by the industry. The outcomes were used to make recommendations to close identified gaps and to encourage strategies for "transatlantic" cooperation and knowledge exchange within the framework of rail higher education. The outcomes also provide existing programs with information to benchmark and compare themselves with their peers and provide assistance in the development of new programs.

Six basic tasks were undertaken to achieve the project objectives. Each task had a task leader but the whole team worked in a collaborative manner to produce outcomes for all tasks. The tasks included the following:

This "*Handbook for Rail Higher Education*" is one of the important outcomes of the project. In addition to the Executive Summary, the Handbook is divided in to four chapters that summarize the research findings and provide recommendations for strategies and activities that can enhance the rail higher education within and between E.U. and the U.S.

Table 1.1 – List of tasks

Task Number	Task Title
T.1	Data Collection
T.2	A Comparative/Evaluation Study
T.3	Identification of Innovative and Successful Educational Practices
T.4	Recommendations / Strategies for Enhanced Knowledge Transfer and for Program Development / Improvements
T.5	Dissemination of Research Outcomes and Collected Data
T.6	Project Management and Evaluation

Chapter 2: European and North American rail systems are different, but the gap is diminishing from multiple reasons, both internal and external to the railway industry.

Chapter 2 describes the TUNRail project scope and tasks in more detail and provides an overview of both the E.U. and U.S. The chapter also provides an introduction to the types of passenger and freight rail and compares the rail systems in the E.U. and U.S. It was recognized early in the study that a system comparison is important as the different history and nature of the systems provide demands and requirements that should be considered in the rail higher education. The key findings of the system comparison include:

- The E.U. rail system is heavily oriented to passenger traffic with modern infrastructure and equipment while the U.S. system is primarily freight-oriented with localized areas of high-density passenger train operations. Accordingly, the market share of rail is much higher for passenger rail in the E.U., while it is much higher for freight rail in the U.S.
- The E.U. systems have much larger public participation, including management, operation and funding of existing and new systems while the U.S. system has limited, but growing, use of public-private partnerships and other public participation.
- The development of rail transportation relies typically on incremental improvements. The priority of rail development in E.U. has slowly shifted toward freight rail while development of higher speed passenger rail has increased in priority in the U.S.
- The trends towards privatizing and enhanced freight rail in the E.U. and the high speed passenger rail initiatives managed by the federal government in the U.S. are reducing the differences between E.U. and U.S. systems.

- There is considerable resistance and challenges in the E.U. to embrace new system characteristics such as multiple private operators in one system with interoperability capabilities). In the U.S., development of new, and in many cases shared, passenger and freight corridors and infrastructure will be major challenges.
- The number of people employed in the railway sector seems to be significantly higher in the E.U. than in the U.S, but aging of workforce is a common challenge. The number of people directly employed by railway operators in the E.U. is 1.3 million, while in the U.S., the total number of employees in freight and passenger rail and related support industries is over 600,000. However, lack of comprehensive data makes analysis and a direct comparison very difficult.

Chapter 3: Infrastructure for Rail Higher Education is more Extensive and Developed in the E.U. than in the U.S.

Chapter 3 describes the outcomes for one of the primary objectives of the TUNRail. The research team collected data that explored the similarities and differences between the E.U. and U.S. rail higher education to present a portrait of current university-level programs and courses. The study gathered institutional data through electronic survey from universities with formal railway educational and/or research programs, as well as from universities that offer classes in railway transportation and engineering. Six programs familiar to the research team in the E.U. and U.S. were described as case studies. Some of the key findings include:

- Lack of central data source or repository for rail higher education programs and language barriers (in E.U.) made data collection effort challenging, but the current levels of railway education and research in academia are considerably more extensive in the E.U. than in the U.S (Table 1.1).
- The number of universities engaged in research in the U.S. and the E.U. appears to be similar, but it is expected that, upon further investigation, the average amount of research at each university in the E.U. and U.S. (measured by graduate students and researchers, funding, etc) would be much larger in the E.U..

- The total number of students receiving rail education is approximately 150-250 per year in the U.S. and 1,000-3,000 in the E.U.. The findings demonstrate that a majority of students receiving a degree in civil engineering or in transportation in the E.U. obtain some level of education in railways while in the U.S., rail education as a part of a traditional civil engineering curriculum is very rare. On the other hand, the ten-fold quantity for the E.U. side results from the fact that at many universities, rail education is required for all civil and transportation engineering students.

Table 1.2 - Summary of US and E.U. Railroad Transportation Education and Research Programs and Individual Railway Course Offerings (Note: some numbers are approximations)

Description	**US**		**E.U.**	
Number of universities with railroad programs (research and teaching combined)	2		21	
Number of universities with railroad research activity	19		---	
Number of universities with railroad courses	12		---	
Number of railroad courses offered	19		260	
	Range	**Average**	**Range**	**Average**
Number of faculty and staff at each research institution	1-6	3*	3-50	10
Number of graduate students engaged in railway research	4-14	7.5	5-20	10
Number of undergraduate and graduate students enrolled in railway courses	3-15	5.6	20-200	100
Number of railroad courses offered per university teaching railroad transportation	1-6	1.8	5-20	10

- Beyond the number of the railroad courses, there are several similarities and differences between the course content in the E.U. and U.S. The U.S. courses tend to concentrate more on engineering, mainly related to civil engineering (rail infrastructure engineering) or introductory courses that cover topics from multiple disciplines, whereas E.U. also offers courses in the facilities, operations and systems area. Figure 1.1 presents a summary of E.U. course topics.

- Since university rail education has been well established for decades in the E.U., there is no general trend for a further growth. University railway education in the U.S. has almost totally disappeared over the past decades, but recently efforts have been started to rebuild these capabilities. Most academic faculty in the E.U. are funded from general funds, while many railway faculty in the U.S. are in non-tenure track positions that are funded by the rail industry.
- Universities in E.U. embrace the idea of research oriented teaching, but in U.S, industry is primarily interested in BS and MS level education. As a result, there are few graduate level railway courses offered in the U.S.
- In general, the demand for rail education in both the U.S. and the E.U. is expected to grow in the coming years.

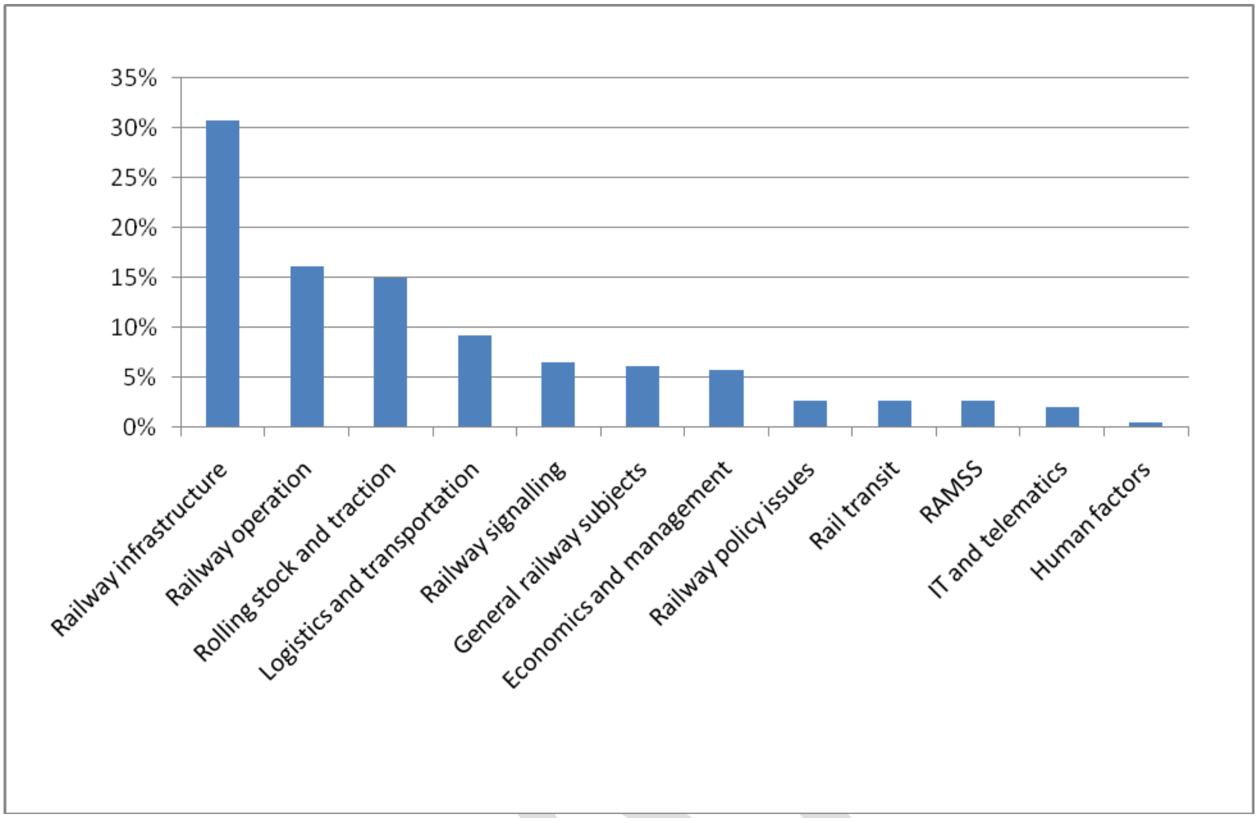

Figure 1.1 - Subjects Covered in E.U. Railway Courses

Chapter 4: Industry demand for graduates is expected to increase and transatlantic collaboration is considered beneficial. However, current education doesn't seem to meet all the priorities by the industry.

Chapter 4 presents the outcomes of an online industry survey on the quantitative and qualitative demands for university graduates and for rail higher education in general. The Chapter also summarizes a competence gap analysis conducted from the outcomes of university and industry data collection. Almost 600 industry professionals from several backgrounds responded to the industry survey that consisted of two separate parts. The first (shorter) part was targeted at all rail industry professionals and it concentrated on learning more about their background and their path to the industry, as well as getting opinions on the importance of university involvement in the field. The second part was mainly targeted at managers of younger professionals and those involved in recruitment and training. This part included more detailed questions on university education and industry collaboration, and identifying important competences and skills for new industry professionals. Some of the findings included:

- Majority of respondents in the U.S. consider current rail higher education inadequate, while in E.U., the majority considers it adequate.
- Large percentage of respondents expect that the demand for new industry employees will increase within next five years
- Transatlantic collaboration was considered beneficial by a large majority of respondents.
- In the U.S., the greatest perceived benefits of university involvement in the field were related to education and promotion of the field, while in E.U. they were directed more toward enhancements through research activities. The current methods of university collaboration in the U.S. focus on internships and guest lectures, while in the E.U. collaborative research was more common.
- Time commitment was considered major hindrance or obstacle for university partnerships
- The competence gap analysis in the U.S. was limited by the low overall number of available courses.
- The competence gap analysis revealed a presence of competence gaps in both the E.U. and U.S., although there are some differences. The most visible competence gap was related to the competence *environment* which is highly valued in both European Union (ranked first) and the United States (ranked second), but no courses were identified that provided this type of competence.
- Competence gap analysis also suggest a difference between industry and academia, as the industry's most valuated competences were not reflected in the main topics covered by the current academic courses. The main exception occurred in the U.S. where the competence *civil engineering and infrastructure* was the most valued, and the number of courses concerning this competence is second to the *multidisciplinary (introductory) course*.
- Most courses concentrate on a limited domain area of knowledge, mainly in civil engineering and transportation (in E.U.). No specific courses were identified in the potential relevant domains such as mechanical engineering or systems engineering.

Chapter 5: Innovative teaching methods exist, but rail higher education has not moved to global education and taken advantage of educational technologies.

Chapter 5 provides an overview of activities and alternative methodologies that could be used to transform the current education processes to be more globally oriented and it describes a few examples of innovative teaching strategies that have been implemented in the rail higher education. Some of the findings included:

- Global education extends beyond technical skills to ethical, cultural, language and team leadership aspects.
- The approaches toward more global education vary significantly both in methodology and in the extent of activities. The use of technology has lowered the entrance barrier significantly, as it allows global education approaches without physical travel. Some examples of global education range from traditional study abroad programs to E-learning and virtual classrooms.
- Railway engineering differs from teaching many other fields of technology, as in the railway system all fields of engineering are interconnected (Figure 1.2). As a result teaching railway science must follow an interdisciplinary approach where fundamental knowledge of rail related aspects of civil engineering (permanent way, structures), mechanical engineering (rolling stock), electrical engineering (signaling, electric traction), and computer science (signaling, control systems) come together in the process of operation.

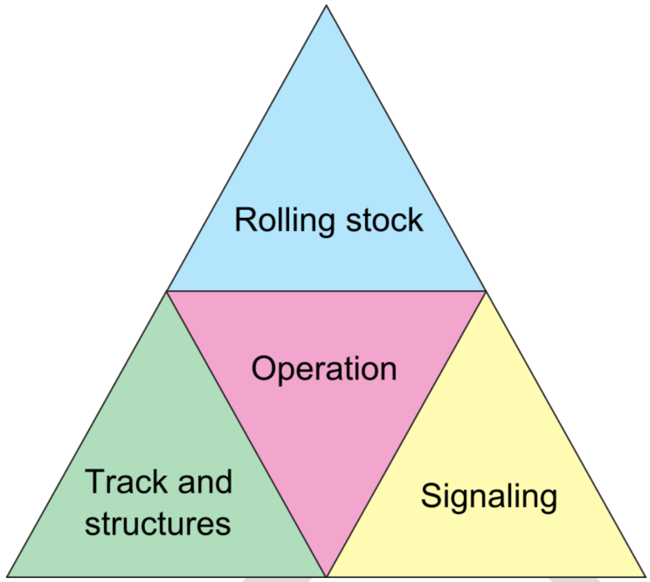

Figure 1.2 - The railway systems triangle

- Cooperative rail operations labs and simulators (especially in Germany) are good examples of innovative hands-on methodologies for rail higher education.
- Examples that use of internet applications and online technologies for rail higher education are very limited, both in the E.U. and U.S.
- While there is considerable interest in offering collaborative and synchronous education for students in the E.U. and U.S., differences in time and semester schedules are major hindrances for collaborative transatlantic learning process.
- The E.U. has initiated an interesting project, SKILLRAIL, aimed at the creation, dissemination and knowledge transfer within the railway sector in Europe. The framework, called E.U.RAIL "European University of Railway", is intended to be a virtual training environment ensuring concentration of high-level knowledge and expertise in one single location.

Chapter 6: Recommendations and Strategies for Enhancing Railway Higher Education

Chapter 6 concludes the Handbook and provides recommendations and strategies for universities and the rail industry to improve rail higher education to meet the current demands. The objective was to develop recommendations that were supported by the collected data and highlight some of the advantages and disadvantages of each strategy and activity. A discussion of each recommendation is provided in Chapter 5. The strategies are grouped in three categories and then divided into several topics in each category. The categories and topics include:

- Data collection / research activities
    - Establish rail higher education data repository to store and disseminate data on available educational offerings in E.U. and U.S. and to support easier identification of synergies between universities.
    - Continue rail system comparisons between E.U. and U.S. with emphasis on developing a set of metrics for both sides of Atlantic.
    - Initiate transatlantic research effort to identify areas of development with high priority for both E.U. and U.S. and investigate opportunities for collaborative research in these areas.
- Education and technology development
    - Establish an internet based knowledge database and related web portal to collect rail-related knowledge from university teachers from different parts of the world.
    - Establish more hands-on rail laboratories, either physical or virtual and make them available for students from other locations through web technologies. Use of other types of education that takes advantage of technology, such as computer games and simulations should also be expanded.
    - Create technical content independent of national rules and principles to allow its better use for international education.
    - Expand course content beyond civil engineering and transportation.
    - Emphasize the importance of non-technical skills recognized important for global engineers in the education process. Identify opportunities to include (require) these skills to the learning process.
- University / industry and transatlantic collaboration development
    - Develop strategies (or roadmaps) for industry on how to develop university / industry collaboration
    - Develop joint international activities (preferably in collaboration with industry) that allow increased interaction between the E.U. and the U.S. students.

- Take steps to redevelop the U.S. academic infrastructure in rail higher education. Investigate opportunities for faculty visits by the E.U. professors to assist in the process.
- Consider railway education through research, such as joint MS or PhD programs that include mandatory visits by candidates in the other side of Atlantic.
- Encourage the development of collaborative transatlantic programs in rail transportation, such as MIT / IST program

Appendices: University course and industry survey data

The complete dataset on university rail programs and courses in the E.U. and the U.S. is included in Appendices A and B. Appendix C provides a complete list of questions in the online industry survey.

2 Introduction to the TUNRail Project and Rail Transportation in the European Union (E.U.) and the United States (U.S.)

2.1 Background

During the past several decades, university higher education programs relating to rail transportation have been reduced or eliminated due to low demand. This development is troubling as these programs are key components in securing the future professional workforce for an industry that is facing an unprecedented level of retirements within the next five to ten years. Future rail transportation professionals who serve in the diverse railway institutions must be able to master an increasing level of new information technologies and system complexities which differ from the historical concepts that concentrated more on local issues. Such a critical need must be addressed in railway higher education and today's programs should be more globally oriented.

In addition, challenges exist due to the vast differences between E.U. and U.S. railway transportation systems, as their development has historically had different priorities and authoritative structures. While this is the case, there is a growing sentiment that the latest efforts in both sides of Atlantic have encouraged developments that would bring these systems closer to each other. The E.U. has made improvement of freight rail transportation a high priority which has traditionally been considered strength of the U.S. system. Simultaneously, the U.S. Federal Government and majority of the States have become more interested in developing a high speed passenger rail system to complement its existing freight rail system, an area with decades of experience in the E.U.. Even though the systems have had different priorities, the improvement methods for both scenarios include incremental approach, such as speed increases of freight or shared lines in the U.S., and development of new lines, such as construction of new TGV lines in France. In addition, the desire to improve the existing railway systems in both the E.U. and U.S., has been largely precipitated by the necessity to adapt to the new realities of the modern economy, such as the development of free trade, globalization, emissions and energy consumption. All these factors support the notion that need for transatlantic cooperation and harmonization has probably never been higher. The growing synergies, interest and increasing complexity of railway systems warrants an extensive re-evaluation of the educational programs needed to adequately address these emerging challenges.

2.2 Introduction to TUNRail

The Policy Project on Tuning Transatlantic Cooperation in Railway Higher Education (TUNRail) was intended to study and define benchmarks for the study of railways and foster collaboration between the E.U. and the United States. The consortium partners consist of five universities and two external evaluators. The lead universities are Michigan Technological University and Instituto Superior Tecnico (Portugal) in the U.S. and E.U., respectively, and the University of Illinois at Urbana-Champaign and the Technische Universität Braunschweig (Germany) are partner universities for this study. In addition, researchers from University of Newcastle upon Tyne (United Kingdom) are involved. The two external evaluators are Mr. Thomas White of Transit Safety Management, Inc. (U.S.) and Prof. John Preston from the University of Southampton (United Kingdom).

Lead Institutions

Partner Institutions

The project was funded through an E.U.-US Atlantis grant from the Fund for the Improvement of Postsecondary Education (FIPSE), the US Department of Education, and the Executive Agency for Education Audiovisual and Culture (EACEA), a branch of the European Commission.

The focus of TUNRail was to develop a "transatlantic" function within the framework of railway higher education that enhances the knowledge exchange between the E.U. and U.S. and secures a robust collaboration on areas with transatlantic synergies. In essence, TUNRail was meant to compare and fine tune the current learning outcomes and competencies that exist between the E.U. and U.S. The key focus of the project was to develop an understanding of railway higher education programs, the differences in railway systems and higher education on both sides of the Atlantic, and explore areas for future cooperation and synergy. The project also allows current programs to benchmark and compare themselves with their peers and provide assistance for potential new programs in their development process. The project was conducted between September 2009 and August 2011. The main tasks and time line for the project is presented in Figure 2.1.

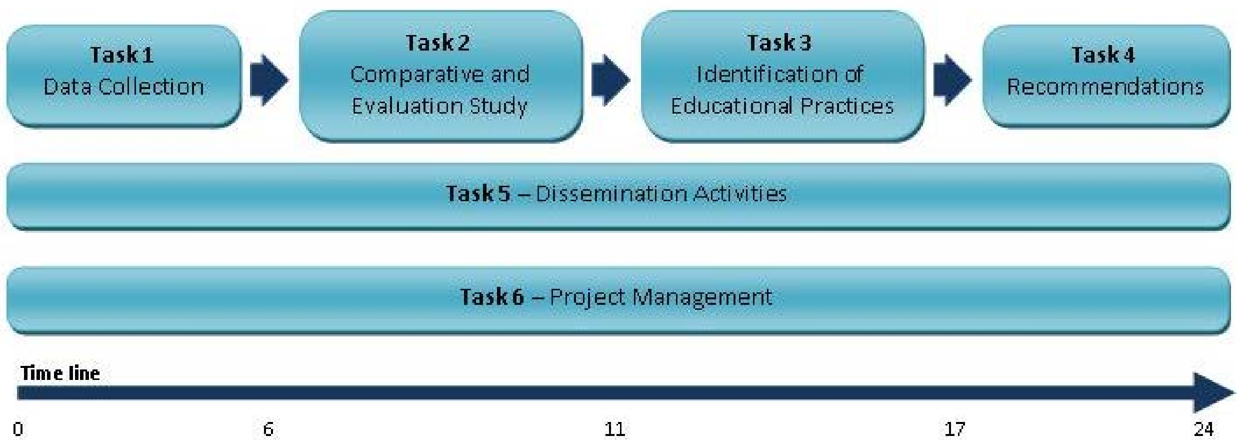

Figure 2.1 TUNRail Project Tasks and Timeline

Six consecutive and parallel tasks were conducted to achieve the project objectives. Each task had a task leader but the whole team worked in a collaborative manner to produce the outcomes for all of the tasks. The detailed objectives and subtasks were as follows:

Task 1: Data Collection

The objective of Task 1 was to develop a comprehensive inventory of current railway higher education programs and activities in the U.S. and E.U. and to determine the demand for

railway higher education by the industry, both quantitatively and qualitatively. The task also established a web based railway education forum as a tool for stakeholders to provide input and suggestions to the project.

The sub-tasks for Task 1 included:

- **Task 1.1** A survey on the current practices and study programs for railway higher education in the U.S. and E.U..
- **Task 1.2** Targeted on-line survey and industry interviews to define the need for higher educated professionals and competences required by the rail industry sector in the U.S. and E.U..
- **Task 1.3** Development of a web based railway education forum (E-forum) with open access, as a tool for stakeholders to provide input and suggestions to the project and railway education.

Task 2: Comparative and Evaluation Study

The objective of Task 2 was to utilize the information collected in Task 1 to perform comparative analysis between the current programs in the E.U. and U.S. and to analyze whether these programs are sufficiently addressing the needs of the railway sector, both quantitatively and qualitatively. This task also investigated the synergies between the railway systems and railway higher education programs in the U.S. and E.U..

The sub-tasks included:

- **Task 2.1** Coordination with Task 1 to obtain a dataset for comparative and evaluative analysis.
- **Task 2.2** Selection and implementation of appropriate comparative/evaluation methods (benchmarking, statistical methods, ranking methods, Data Envelopment Analysis, etc.). The method has been selected based on the extent and quality of data collected in Task 1 and on the probability for the method to provide significant outcomes from available data.
- **Task 2.3** Comparison of quantitative and qualitative demand and supply for railway higher education and evaluation of the current programs to sufficiently fulfill the demand.

- **Task 2.4** Identification of the synergies between the railway systems and railway higher education programs in the U.S. and E.U..

Task 3: Identification of Educational Practices

The objective of Task 3 was to identify innovative and successful practices of the current railway higher education programs and provide brief case studies of those practices.

The sub-tasks included:

- **Task 3.1** Investigation of the most innovative and successful practices in education and approaches toward more globally oriented education, based on the data analysis obtained during the previous tasks.
- **Task 3.2** Development of a deeper understanding of identified practices and successful stories by performing in-depth analysis and case studies of available material.
- **Task 3.3** Description of example laboratories and models (including software simulations) used in higher railway education and by other fields. This includes the modes of use, e.g. contract-based shared used of laboratory facilities by several universities.

Task 4: Recommendations

The objective of Task 4 was to develop specific recommendations and strategies for enhanced transatlantic knowledge transfer and development of new programs or improvement to current programs.

The sub-tasks included:

- **Task 4.1** Review of materials developed and analysis performed in the Tasks 1 through 3 and identify promising approaches, activities and methods to enhance learning outcomes, competences and other relevant aspects of railway higher education.
- **Task 4.2** Collaborative effort by the research team to evaluate the reviewed material and to develop specific recommendations for 1) enhanced transatlantic knowledge transfer, 2) development of new programs and 3) improvements to current programs.
- **Tasks 4.3** Development of strategies for universities and rail industry to improve the relevance of railway higher education to meet the current demands. Development of

strategies for implementing new railway higher education programs, if demand for additional programs is identified in Task 2.

Task 5: Dissemination Activities

The objective of Task 5 was to use several methods to reach a wide stakeholder audience on both sides of the Atlantic for dissemination of the study and results.

The sub-tasks included:

- Tasks 5.1 Establish a project web site that consolidates study objectives, plans and research outcomes to one physical location.
- Task 5.2 Continuously monitor E-Forum developed in Task 1. Manage and participate in the dialog with external stakeholders.
- Task 5.3 Produce and disseminate semi-annual electronic newsletters at 6, 12, 18 and 24 months of the project.
- Task 5.4 Develop an electronic handbook that consolidates all the material developed in Tasks 1 through 4 to a one cohesive document and publish it on the web page. The handbook is envisaged to provide necessary background and important information to assist individuals and agencies interested in railway higher education to either implement a new program or improve a current program.
- Task 5.5 Organize a transatlantic web conference at the end of the project to disseminate the study results to the stakeholders and to solicit feedback and recommendations for the next steps in the development of railway higher education.

Task 6: Project Management

The objective of Task 6 was to coordinate the efforts of coalition members and ensure that the project meets the contextual, fiscal and evaluation requirements, as outlined by Atlantis program officers.

The sub-tasks include:

- **Task 6.1** Coordinate and monitor the progress of individual team members and tasks. Articulate the progress in a timely manner with the European Commission and the U.S. Department of Education via progress reports outlined in the project instructions.
- **Task 6.2** Coordinate and administer the project budget according to activities, participating institutions and time.
- **Task 6.3** Organize team meetings and member participation in Atlantis conferences.

- **Task 6.4** Manage all potential risks and conflicts during the lifetime of the project.
- **Task 6.5** Coordinate with the project evaluators in a timely manner to secure that high quality standards and progress is made according to the project work plan (i.e., Tasks 1 through 6).

The consortium partners believe that TUNRail was the first time that a multilateral U.S.-E.U. policy oriented measures project had been proposed to "tune" current educational programs and intensify transatlantic cooperation in railway higher education. TUNRail was built on several years of discussions between consortium partners to initiate increased collaboration and stands as an innovation in bridging the knowledge gap between the E.U. and U.S. It was a critical project due to increasing interest for modern "non-traditional" rail transportation and the demand for a more "global" approach. Another innovative element was the extensive use of internet and live web conferences for communication and interaction among the project partners (research team and evaluators) and tools to secure stakeholder input and participation in the process, and disseminate project news and outcomes to the stakeholders. The outcomes of this project will help to encourage increasing transatlantic collaboration using technology by the railway education and industry sector.

TUNRail directly impacts all academic institutions within and outside the E.U. and U.S. that currently participate in railway higher education or are considering an entry into the field. Both academia and industry benefit from the increased transparency and collaboration between stakeholders in each continent. As the demand for rail transportation and railway higher education increases, the information disseminated through TUNRail helps provide assistance and encourages the development of new "globally oriented" railway programs. Railway systems and industries are impacted by the increased number of program graduates for employment, as well as by the use of new technologies unveiled through research activities. Other transportation industries that closely collaborate with the railway industry, such as transportation equipment, technology companies, and companies who use railways are also affected.

Finally, TUNRail identifies new opportunities for current and future university students who are making decisions on their future careers as they are provided with information on opportunities within railway higher education and the railway industry. TUNRail outcomes have been utilized to entice a wider group of institutions in both the short term and the long term. In the short term, the main concentration was in "*mainstreaming the results*" by providing and disseminating study outcomes to appropriate decision-makers and institutions. In the longer term, the objective was in "*multiplication of railway higher education*" by convincing potential beneficiaries to study, adopt and further apply the TUNRail outcomes as part of their activities.

2.3 Limitations of the Study

During the investigations, it became apparent that certain limitations needed to be put in place. These limitations were necessary to maintain appropriate project scope and to guide the proper use of resources. Some of the key limitations and related outcomes included:

- The project concentrated mainly on rail higher education related to engineering and operations. Other areas of concentration, such as economics and management, are of equal importance, but the project team expertise was best suited for the engineering areas and resources were not available to complete industry-wide assessment.
- It was recognized that developing inventory of rail higher education in the E.U. was extensive and labor some, as there are numerous alternative approaches for providing such education. The outcomes presented in the report concentrate on traditional full semester university courses in rail transportation and inventory should not be considered comprehensive, but rather indicative of the overall supply. Other significant contributors to education and training, such as industry training programs, were not investigated in the study.
- The data collected as part of the project was fragmented and not sufficient to provide comprehensive set of strategies to improve the current situation. Therefore, significant portion of project recommendations are suggested topics for further investigations to close some of the data gaps.

2.4 Comparison of Rail Systems in the U.S. and E.U.

It was recognized early in the project that providing meaningful ideas for improved rail higher education would be difficult if the underlying differences in societal and transportation systems between U.S. and E.U. were not understood. The following section provides an introduction of both regions and some basic comparisons between the rail systems.

2.4.1 Introduction to the E.U. and the U.S.

Europe is one of the smallest of the continents in terms of area but one of the largest in population. Europe extends from the Arctic Ocean in the north to the Mediterranean Sea in the south and from the Atlantic Ocean in the west to the Ural Mountains in the east. The 48 countries of Europe include part of the world's largest country, Russia, as well as the world's smallest, Vatican City. Russia, it should be noted, is divided between Europe and Asia. Figure 2.2 shows a map of Europe.

Over 700 million people live in Europe of which 105 million people live in the part of Russia that lies in Europe. The people of Europe represent a variety of cultural backgrounds and for centuries they have spoken different languages and followed different cultural traditions. There are over 50 languages and more than a hundred dialects spoken in Europe.

The European Union (E.U.) is an economic and political union of 27 sovereign states or countries located primarily in Europe.[1] The E.U. traces its origins from the European Coal and Steel Community formed by six countries and the Treaty of Rome in the 1950s. Today, the member countries include Austria, Belgium, Bulgaria, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, Sweden, and the United Kingdom.[2]

The E.U.'s member states have a population of almost 500 million people and cover an area of 4.5 million square kilometers (1.7 million square miles). The population is highly urbanized with over 80% of people living in urban areas. There are 16 cities with populations of over one million. The three largest cities are London (7.5 million), Berlin (3.4 million), and Madrid (3.2 million).

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[1] "A Growing Union," E.U.ROPA, accessed July 25, 2011, http://europa.eu/about-eu/countries/growing-eu/index_en.htm.
[2] "Countries," *E.U.ROPA*, accessed July 25, 2011, http://europa.eu/about-eu/countries/index_en.htm.

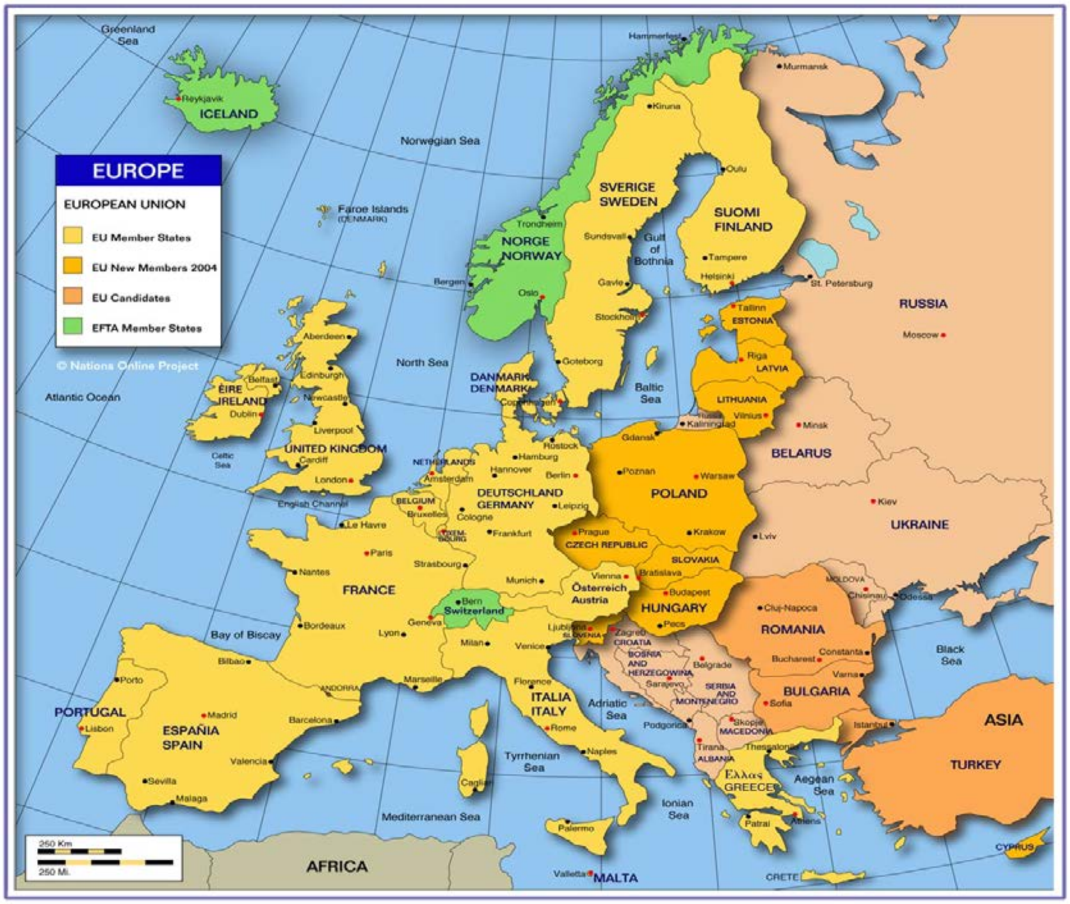

Figure 2.2 - The European Union with Non E.U. Countries[3]

The E.U. has developed a single market through a standardized system of laws which apply in all member states ensuring free movement of people, goods, and services. Seventeen member states that belong to the European Monetary Union (EMU) have adopted the Euro as a common currency.[4]

The United States of America (USA) is the third largest country in the world in population and the fourth largest country in land area. It covers the entire mid section of North America, stretching from the Atlantic Ocean in the east to the Pacific Ocean in the west. Canada lies north and Mexico is to the south. The United States also includes Alaska in the northwest corner of North America and Hawaii in the Pacific Ocean. The United States consists of 50 states and the

3 One World – Nations Online, accessed July 25, 2011, http://www.nationsonline.org/maps/countries_europe_map.jpg

[4] Kelch, David et al., "European Financial Imbalances: Implications of the Eurozone Sovereign Debt Problem for U.S. Agricultural Exports," *United States Department of Agriculture*, accessed July 25, 2011, http://www.ers.usda.gov/Publications/WRS1102/WRS1102.pdf.

District of Columbia. The District of Columbia is a piece of land set aside by the federal government for the nation's capital, Washington, D.C. The U.S. has a federal system of government which gives states many powers that national governments have in other countries. In terms of area, population, and economic output, some of the states are comparable to many nations. Figure 2.3 shows a map of the United States.

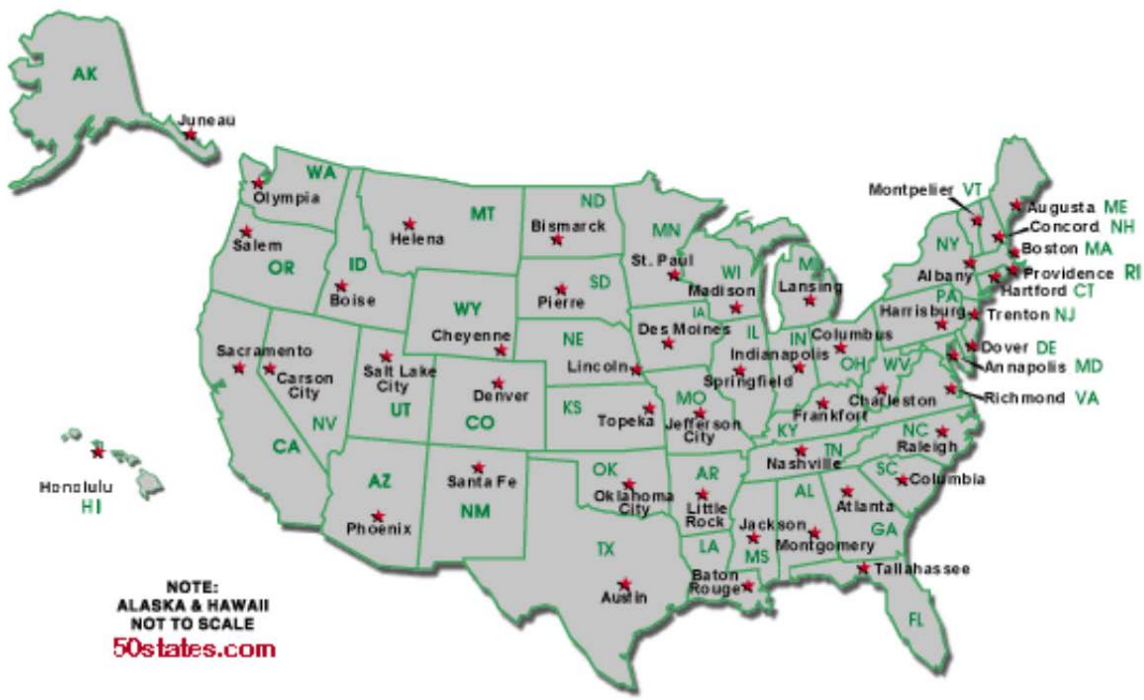

Figure 2.3 - Map of the United States[5]

The population of the United States is over 300 million people and the largest states (in order) are California, Texas, New York, and Florida. Currently, about 80 per cent of the citizens live in urban areas. There are 9 cities with over one million people. New York City with almost 8 million people is the largest U.S. city and Los Angeles is the second largest with 3½ million people. Nearly 3 million people live in Chicago and six other cities have over 1 million people – Houston, Phoenix, Philadelphia, San Antonio, San Diego, and Dallas. Like Europe, many U.S. cities are surrounded by suburbs in units that are often called "metropolitan areas". The New

[5] 50 States.com, accessed August 12, 2011, http://www.50states.com/cap.htm

York – Northern New Jersey – Long Island metropolitan area (locally referred to as the “Tri-State Region”) is the largest metropolitan area in the U.S. with more than 18 million people.

Table 2.1 summarizes the population, land area, population density, and capital city for the E.U. countries and the United States. In terms of population, Germany, France, and the United Kingdom are the three largest countries in the E.U. While overall the E.U. population exceeds U.S., the individual countries within the Union have significantly lower populations than U.S. In general, nationwide population density should be used with caution when making transportation analysis. A more meaningful measure would be population density within specific regions or states.

Table 2.1 - - The E.U. and U.S. Overview

Country	Population (million)	Land Area (km^2)	Population Density (persons/km^2)	Capital City
Austria	8.4	84,000	100	Vienna
Belgium	10.8	30,500	355	Brussels
Bulgaria	7.6	110,900	68	Sofia
Cyprus	0.8	9,300	87	Nicosia
Czech Republic	10.5	79,000	132	Prague
Denmark	5.5	43,000	128	Copenhagen
Estonia	1.3	45,000	29	Tallinn
Finland	5.4	338,000	16	Helsinki
France	62.8	675,000	114	Paris
Germany	81.8	357,000	230	Berlin
Greece	11.1	132,000	86	Athens
Hungary	10.0	93,000	108	Budapest
Ireland	4.4	70,000	63	Dublin
Italy	60.4	301,000	200	Rome
Latvia	2.2	65,000	35	Riga
Luxembourg	0.5	2,600	195	Luxembourg
Malta	0.4	300	1320	Valletta
Netherlands	16.6	42,000	400	Amsterdam
Poland	38.2	313,000	122	Warsaw
Romania	21.5	238,000	90	Bucharest
Slovakia	5.4	49,000	111	Bratislava
Slovenia	2.0	20,000	102	Ljubljana
Spain	46.1	506,000	91	Madrid
Sweden	9.0	450,000	21	Stockholm
United Kingdom	62.0	245,000	255	London
E.U.ROPEAN UNION (TOTAL)	499.2	4,460,000	170	N/A
UNITED STATES	309.6	9,830,000	32	Washington

Note: Country and total population and areas have been rounded

2.5 Transportation in the E.U. and the United States

Both the European Union and the United States have highly developed transportation networks where airlines, railways, waterways, and highways provide efficient systems for the movement of people and goods. Tables 2.2 and 2.3 show the distribution of freight and passenger traffic by transportation mode in the E.U. and the United States.

Table 2.2 - Freight Transportation (billion tonne-kilometers), 2008

Mode	**European Union**	**United States**
Road*	1,878 (46%)	1,923 (31%)
Rail	**443 (11%)**	**2,657 (43%)**
Inland Waterways	145 (3%)	472 (8%)
Oil Pipeline	124 (3%)	814 (13%)
Sea (domestic / intra E.U.)	1,498 (37%)	333 (5%)
TOTAL	4,088 (100%)	6,199 (100%)

** Intercity Trucks only*

Table 2.3 - Passenger Transportation (billion passenger kilometers), 2008[6]

Mode	**European Union**	**United States**
Private Auto	4,725 (72%)	7,202 (85%)
Motorcycles	155 (2%)	30 (< 1%)
Bus	547 (8%)	243 (3%)
Rail	**409 (6%)**	**37 (< 1%)**
Tram and Metro	89 (1%)	21 (< 1%)
Water	41 (1%)	0.6 (< 1%)
Air (domestic / intra E.U.)	561 (9%)	939 (12%)
TOTAL	6,527 (100%)	8,512 (100%)

Note: Tram and Metro = streetcars/LRT and heavy rail transit

Railways and inland waterways were once the most important mode for goods and passengers in

[6] "Energy and Transport in Figures," *European Union: European Commission Directorate for Energy and Transport*, 2010, accessed July 26, 2011, Tables 3.1.12 and 3.3.2, http://ec.europa.eu/energy/publications/statistics/doc/2010_energy_transport_figures.pdf.

Europe. However, today almost half of the E.U. freight, in terms of tone-kilometers, is shipped by truck and almost three-quarters of passenger transportation is by private automobile.

A sprawling transportation network spreads out over the United States. Americans use automobiles for most of their personal travel and the highway system is primarily the responsibility of state and local governments. The U.S. Dwight D. Eisenhower National System of Interstate and Defense Highway system was initially built with federal funding and then turned over to the states to operate and maintain. In addition to state gasoline and registration taxes to support state highway transportation networks, the federal government collects gasoline taxes and then transfers funds to states for highway and local transit development projects and operations. Privately owned and operated railroads are the leading freight carriers handling almost 45 per cent of the U.S. intercity freight when measured in ton-miles, but railroads account for less than 1 per cent of all passenger traffic. Trucks carry nearly 30 per cent of intercity freight ton-miles in the United States, but when the value of shipments is considered, their share is 75 per cent. The airlines handle over 10 per cent of U.S. domestic passenger traffic but less than 1 percent of the freight traffic.

During the 1950s, the share of freight carried by railroads was similar and declining in both the United States and Europe. Beginning in the 1960s, however, the trends diverged. In the United States, the decline slowed during the 1960s and 1970s, and railroad share of freight actually increased during the 1980s and 1990s. In contrast, European rail freight share steadily declined throughout this period. By 2008, the railroads share of freight (measured in tonne-kilometers) had increased to 43% in the United States while it fell to 11% in Europe.

One possible explanation is the difference in geography and other natural or inherent characteristics make the United States more suitable for rail freight than Europe. The United States has three times the land area of the European Union, which results in longer shipment distances that favor railroads over trucks. Furthermore, the United States, despite its land mass, has only one-ninth of the coastline of Europe, favoring railroads over coastal shipping. The mix of commodities shipped differs between the United States and Europe as well, and often in ways that bolster United States' railroad share.

An alternative explanation is that public policies have traditionally concentrated on passenger rail at the expense of freight rail in Europe while in the United States passenger rail has received very little government attention and investment. Europe has higher taxes on motor vehicle fuels and a long history of subsidizing its railroads and although both Europe and the United States have built extensive high-performance highway systems, in Europe these are often financed by tolls while in the United States many are not. On the other hand, the United States has encouraged its freight railroads to be more efficient by leaving them in private hands instead of nationalizing them as is the case in Europe. Moreover, the United States released the private railroads from the obligation to provide urban commuter rail service in 1958 and intercity passenger service in 1970, and then substantially eliminated government controls over freight rates in 1980, three steps which allowed railroad managers the freedom and flexibility to focus on freight. (Vassallo, 2007) Since 1980, U.S. freight railroads have increased their volume and productivity significantly by concentrating on the corridors with highest volumes and best opportunities for profitable operations. However, some argue that this emphasis does not necessarily meet the needs of the national transportation system or to the systematic costs due to modal split.

2.6 Railroad Systems in the E.U. and the United States

Railroads provide two main types of service - freight and passenger service. The importance of each type varies from country to country. In general, freight is the most important aspect of rail operations in the United States while passenger service is more important in Europe.

Table 2.4 presents information on railroad freight and passenger transportation by E.U. country. Germany and Poland are the E.U. leaders in freight transportation while France and Germany are the E.U. leaders in rail passenger transportation. The U.S. rail system handles almost six times more freight than all E.U. railroads combined, but the U.S. rail system transports less than one tenth of the passengers when compared to the E.U. rail systems. One aspect missing from the discussion is the overall utilization of infrastructure which is higher in the European countries than in the U.S.

Table 2.4 - Freight / Passenger Rail Transportation by E.U. Country, 2008[7]

Country	Freight Rail Transportation (billion tonne-kilometers)	Passenger Rail Transportation (billion passenger-kilometers)
Austria	21.92	10.84
Belgium	8.57	10.40
Bulgaria	4.69	2.34
Cyprus	-	-
Czech Republic	15.44	6.80
Denmark	1.87	6.28
Estonia	5.94	0.27
Finland	10.78	4.05
France	40.63	84.97
Germany	115.65	81.76
Greece	10.48	1.66
Hungary	9.87	8.29
Ireland	0.1	1.98
Italy	23.83	49.80
Latvia	19.58	0.95
Luxembourg	14.75	0.40
Malta	-	-
Netherlands	6.98	16.00
Poland	52.04	20.19
Romania	15.24	6.88
Slovakia	3.52	2.30
Slovenia	9.30	0.83
Spain	10.48	23.97
Sweden	23.12	11.02
United Kingdom	24.83	52.68
E.U.ROPEAN UNION (TOTAL)	**442.74**	**409.20**
UNITED STATES	**2656.60**	**37.10**

Note: No rail service in Cyprus and Malta

[7] "Energy and Transport in Figures," *European Union: European Commission Directorate for Energy and Transport*, 2010, accessed July 26, 2011, Table 3.2.5, http://ec.europa.eu/energy/publications/statistics/doc/2010_energy_transport_figures.pdf.

Table 2.5 shows a few characteristics of the infrastructure in the E.U. and the U.S. The extent of road and rail network is somewhat comparable between the E.U. and U.S., but the U.S. has much higher volume of private automobiles than the E.U..

Table 2.5 - Infrastructure and Vehicles in the E.U. and U.S., 2008[8]

Mode	European Union	United States
Road Network (paved) – 1000 km	5,000	4,241
Motorways / Freeways – 1000 km	65	95
Railway Network – 1000 km	**212.8**	**224.2**
Navigable Inland Waterways – 1000 km	43	41
Oil Pipelines – 1000 km	34	269
Private Vehicles - million	232	237
Vehicles per 1000 persons	467	780
Commercial Vehicles - million	34	9

The length of rail lines by each E.U. country and the percent of lines that are electrified are presented in Table 2.6. The extent of electrification varies greatly between countries but overall the majority of the rail network in the E.U. is electrified and the percentage is expected to grow. On the other hand, only a small part of the network in the U.S. is electrified and most trains in the U.S. use diesel power. Germany and France have the largest rail networks in the E.U. while there are no rail lines in Cyprus and Malta.

Table 2.6 - Railway Infrastructure by E.U. Country, 2008[9]

Country	Length of Lines (km)	Percentage of Network Electrified
Austria	5,664	62
Belgium	3,513	84
Bulgaria	4,144	68
Cyprus	-	-
Czech Republic	9,486	32

[8] "Energy and Transport in Figures," *European Union: European Commission Directorate for Energy and Transport*, 2010, accessed July 26, 2011, Table 3.1.11, http://ec.europa.eu/energy/publications/statistics/doc/2010_energy_transport_figures.pdf.
[9] "Energy and Transport in Figures," *European Union: European Commission Directorate for Energy and Transport*, 2010, accessed July 26, 2011, Table 3.5.3, http://ec.europa.eu/energy/publications/statistics/doc/2010_energy_transport_figures.pdf.

Denmark	2,614	24
Estonia	919	14
Finland	5,919	52
France	29,901	52
Germany	33,855	58
Greece	2,552	10
Hungary	7,892	36
Ireland	1,919	3
Italy	16,861	71
Latvia	2,263	11
Luxembourg	275	95
Malta	-	-
Netherlands	2,896	74
Poland	19,627	60
Romania	10,777	37
Slovakia	3,622	44
Slovenia	1,228	41
Spain	15,041	58
Sweden	11,022	71
United Kingdom	16,218	33
E.U.ROPEAN UNION (TOTAL)	**212,842**	**52**
UNITED STATES	**224,200**	**(< 1%)**

Note: No rail lines in Cyprus and Malta

In European countries, the government typically owns and operates a single national rail infrastructure, and governments provide funds as necessary to keep the railroads running. Until recently, the railroads of Europe were owned and operated by the governments of each country. Few trains crossed international borders, service was often considered substandard, and much of the service was subsidized. That began to change with the advent of the European Union. In 1998, the E.U. began a process known as “railway liberalization” to promote competition and improve rail transportation. In essence, the E.U. policy has separated train operation from infrastructure management. Any party can become a licensed railway operator, obtain equipment and personnel, purchase operational capacity to access tracks from the infrastructure manager and go into business transporting passengers or freight. Every railway operator must possess an operating certificate and must pay fees for infrastructure use (“access fees”).

2.6.1 Freight Railroads

In the United States there are 565 railroad companies and all but two of the major railroad companies are owned by private investors. The exceptions are the Alaska Railroad, which is owned by the state government of Alaska, and Amtrak, which operates intercity passenger rail service in the United States. Although railroads are private companies, oversight at the federal level is provided by the United States Department of Transportation (USDOT). Under the USDOT, there are two agencies which oversee rail operations in the U.S. The Federal Railroad Administration (FRA) sets railroad safety standards and inspects locomotives, cars, tracks, and signal systems. The second agency, the Surface Transportation Board (STB), regulates some economic activities of the railroads. For example, STB approval is required if a railroad wishes to merge with another railroad.

The U.S. federal government classifies (or categorizes) freight railroads as either “line haul” or switching and terminal. The government classifies railroads according to operating revenues as Class I, II, and III railroads. The largest railroads are called “Class I” railroads and there are seven Class I railroads – BNSF, CN Railroad (previously Canadian National), Canadian Pacific Railroad (CPR), CSX Transportation, Kansas City Southern (KCS), Norfolk Southern (NS), and Union Pacific Railroad (UP). Figure 2.4 shows the Class I railroads of North America. The line haul companies own the main lines and handle over 90 percent of the traffic. Switching and terminal companies own tracks and other facilities in and around large railroad stations and classification yards and mainly concentrate on short local movements.

Figure 2.4 - Map of the Class I Railroads of the United States[10]

BNSF and Union Pacific (UP) primarily operate in the western United States, while Norfolk Southern (NS) and CSX Transportation operate in the eastern United States. CN Railroad and Canadian Pacific provide service across Canada and have acquired railroads to serve the Central and North Central portions of the United States. The primary freight routes in the United States are oriented east-to-west. Major transfer yards to move cars between railroads are primarily located in Midwestern cities, such as Chicago and Kansas City.

[10] "Class I Railroads," *Wikimedia Foundation Inc.*, 2006, accessed July 26, 2011, http://upload.wikimedia.org/wikipedia/commons/8/8b/Class1rr.png.

A majority of railroad income comes from hauling long-distance freight as railroads provide the most inexpensive method of land transportation over extensive distances. Trains are used extensively to carry such bulk commodities as coal, grain, iron ore, chemicals, and petroleum. They also carry manufactured goods, forest and some agricultural products.

To attract more customers, railroads in many countries have tried several innovative approaches to improve freight services. Among these include the use of unit trains, piggyback services, containerization, and intermodal services to support traditional car-load traffic. Unit trains are freight operations consisting of large quantities of a single commodity which will all be unloaded at a single destination, eliminating the delays of switching required when a train consists of cars with differing destinations. Intermodal trains utilize multiple forms of transportation (rail, highway, shipping, and etc.) to transport goods to their desired destination usually with the use of containerization. Carload or manifest trains carry a variety of car and cargo types. Examples of unit, intermodal, and manifest trains are shown in Figure 2.5 and the distribution of different types of freight moving in the U.S. in Figure 2.6.

European rail freight traffic can also be divided into three categories - Block (unit) trains for coal, steel, and construction materials (35% of the total volume), Single Wagon Load (manifest) trains for chemicals, paper, pulp, and automotive related products (50% of the volume), and combined (intermodal) traffic for containerized goods and finished products (15%). The single wagon load traffic represents the largest share of the E.U. rail freight market, but it has been decreasing in several E.U. countries, as trucks have seen considerable growth in this traffic sector. Overall, the new policies have not improved greatly the E.U. rail freight performance to date and the resulting impact has been decreasing total rail freight market share in the E.U.. The European Commission (EC) has taken notice of this and several measures have been recently taken by them to revitalize the E.U. freight railway sector by setting up a network dedicated to freight services, in addition to creating an integrated, efficient, competitive and safe railway area.

Unit Train (coal)[11]

Manifest Train[12]

Intermodal Train[13]

Figure 2.5 - Three Types of U.S. Freight Trains

[11] "Logistics Green Channel from Changsha to Shenzhen," *Hunan Gov*, 2008, accessed July 26, 2011, http://www.enghunan.gov.cn/wwwHome/200810/t20081005_117723.htm.

[12] *Iowa State Railroad Club*, accessed July 26, 2011, http://www.stuorg.iastate.edu/railroad/Reports/images/KC05/BNSF4807.jpg

[13] Joe Perry,"Pseuod-HDR Images from Cajun Pass," *Chasing Steel*, 2006, accessed July 26, 2011, http://www.chasingsteel.com/blog/tag/cajon-pass-railfan-map.

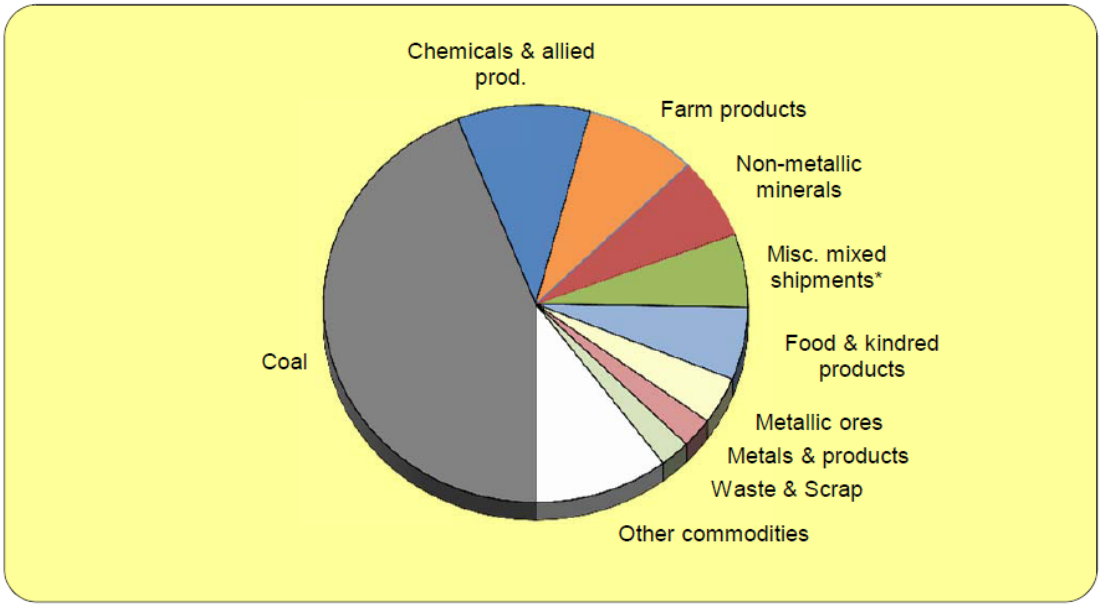

Figure 2.6 - 2010 Class One Railroad Tons Originated[14]

Railroads operate two types of passenger service – intercity and commuter (Figure 2.7). Intercity trains operate between cities and trips take from less than hour to several days to complete and as a result, intercity passenger trains will often have special cars for dining and sleeping in addition to sitting coaches. Commuter trains carry passengers travelling between the central business district of large cities and stations in their surrounding suburbs and their schedules are developed to serve morning or evening work commuter patterns. These trains will typically share track with freight and intercity passenger trains.

[14] American Association of Railroads, *AAR-Stats-2011*, http://aar.org/~/media/aar/Industry%20Info/AAR-Stats-2011-0617.ashx.

Figure 2.7 - Intercity train at Helsinki Railway Station, Finland (Left) and commuter train in California, U.S. (Right)

Since the 1940s, the number of intercity rail passengers has declined sharply in most industrial countries as more people have become accustomed to travel by passenger car or by air. For example, railroads in the United States now carry less than 1 percent of all intercity passenger traffic. However, in some countries, passenger trains have not faced such strong competition from other forms of transportation. People in China, India, and many European countries still rely heavily on trains for intercity transportation.

In 1971, the National Railroad Passenger Corporation (known as Amtrak) was created by the U.S. federal government to take over money-losing intercity passenger operations from the privately owned freight railroads. At the time, many freight railroads were either bankrupt or on the verge of bankruptcy. The quality of their passenger operations was deteriorating rapidly. Today Amtrak operates a 38,000 kilometer route-system serving 500 locations in 46 states. Excluding the sections of track in the Northeast Corridor between Washington, D.C., and Boston, virtually all Amtrak routes operate on freight railroad tracks. Amtrak owns, operates, and maintains its equipment and contracts with the freight railroads to use their tracks for operations. Amtrak is actually a semi-public corporation that is partly financed by the federal government. Amtrak and the USDOT work with the U.S. Congress and local and state governments to determine routes and services.

In Europe, several countries have developed fast intercity passenger trains (Figure 2.8). Of the E.U. countries that have intercity passenger service, over 24 percent of the passenger kilometers are traveled by trains that operate at speeds greater than 200 km/h and in France this number is almost 62 percent of the intercity passengers. Table 2.7 shows the percent of passenger service on high speed trains in E.U. countries and Figure 2.9 presents the extensive integration that exists between countries that belong to the network with streamlined border controls and interoperable equipment.

Figure 2.8 - Map of the High Speed Rail lines in Europe[15]

Table 2.7 - High Speed Passenger Rail Transportation (Speeds over 200 km/h), 2008[16]

Country	Share of Passenger

[15] "High Speed Rail in Europe," *Wikimedia Foundation Inc.*, 2011, accessed July 26, 2011, http://upload.wikimedia.org/wikipedia/commons/8/83/High_Speed_Railroad_Map_Europe_2011.png.

[16] "Energy and Transport in Figures," *European Union: European Commission Directorate for Energy and Transport*, 2010, accessed July 26, 2011, Table 3.5.4, http://ec.europa.eu/energy/publications/statistics/doc/2010_energy_transport_figures.pdf.

	Kilometers by High Speed Trains (%)
Belgium	10
Czech Republic	4
Finland	15
France	62
Germany	29
Italy	18
Netherlands	5
Portugal	13
Slovenia	2
Spain	23
Sweden	27
United Kingdom	2
TOTAL EUROPEAN UNION	24
UNITED STATES	?

The high speed rail development in Europe began with a substantial improvement in conventional passenger rail service and therefore, a typical speed for conventional passenger trains is generally up to 100 mph or even more. In addition to the incremental speed increases, the foundation of the European passenger network has been connectivity where the conventional network is scheduled conveniently to support the high speed network.

Currently, the only high speed passenger trains in the United States are the “Acela” trains which travel up to 240 km/h (150 mph) in the Northeast Corridor between Boston and Washington, D.C (Figure 2.10), but most of the passenger trains have maximum operating speeds of 130 km/h (79 mph). In addition, the current connectivity between Amtrak and local systems is limited at the best. Recently, there has been a renewed interest in high speed passenger service in the U.S. and several initiatives and projects are currently being developed. Figure 2.11 shows the corridors that have been identified by the Federal Railroad Administration (FRA) for the future development of a high speed rail system in the United States.

Figure 2.9 - TGV High-Speed Train in France

Figure 2.10 - Amtrak Acela Train in Northeast U.S. Corridor

Figure 2.11 - High Speed Rail Corridors in the United States[17]

2.7 Urban Rail/Public Transit

Urban rail/public transit systems are common in larger cities in both Europe and the United States. There are three basic categories of urban rail systems – heavy rail, light rail transit and commuter rail. Many of the principles of railroad engineering and design can also be applied to urban rail public transit systems.

Heavy rail is a mode of transit service (also called metro, subway, rapid transit, or rapid rail) operating on an electric railway with the capacity to serve high passenger demands. It is characterized by high speed and rapid acceleration passenger rail cars operating singly or in multi-car trains on fixed rails on exclusive rights-of-way and powered by third-rail electric propulsion. Although most trackage is at-grade, tunnels and elevated structures are used. As an example of heavy rail, Figure 2.12 shows a photo of a Washington Metro train in one of the downtown stations.

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[17] for High-speed Rail in America," *Federal Railroad Administration*, April 2009, accessed July 26, 2011, http://www.fra.dot.gov/downloads/Research/FinalFRA_HSR_Strat_Plan.pdf.

Light rail is a mode of transit service operating passenger rail cars singly or two or three-car trains on fixed rails on a street or on rights-of-way that is separated from other traffic. Light rail vehicles are typically driven by an operator and electric power is drawn from an overhead wire or pantograph. Figure 2.13 shows examples of light rail vehicles in Europe and the United States.

Figure 2.12 - Washington Metro Heavy Rail Train in a Downtown Station

Figure 2.13 - Light Rail Vehicles in Helsinki, Finland (Left) and Minneapolis, Minnesota, U.S. (Right)

Both light rail and metro systems are much more extensively developed in the E.U. than in the U.S. Local government agencies typically own and operate heavy and light rail systems as important components of their public transit network. The urban transit systems have been established for a long time in most E.U. cities, while in the U.S., several new systems have been built over the last 30-40 years to meet the transportation demands in urban areas. New systems are still being developed in the U.S. while in the E.U. most activities evolve around extensions and expansions of current systems. Light Rail is particularly popular in the E.U. where today there are almost 140 systems in operation. Table 2.8 provides a summary by country of the number of cities and route length of light rail and metro systems.

Commuter rail is a mode of transit service provided by electric or diesel-electric powered equipment for urban passenger train service between the suburbs and the central business district in a metropolitan area. In many large E.U. cities, trains are typically electric propelled and they often provide both intercity and commuter rail functions, which makes it more difficult to separate between the two types of passenger rail service. A train may begin a trip on a conventional railroad in commuter rail service but also operate into or through a city as a conventional subway train or metro. Such systems are known by various names, such as S-Bahn in Germany and RER in France

Table 2.8 - Light and Metro Rail Statistics for E.U. and US

Country	Light Rail[18]		Metro[19]	
	Number	Length (km)	Number	Length (km)
Austria	6	313	1	61
Belgium	5	332	1	84
Bulgaria	1	208	1	6
Czech Republic	7	333	1	50
Denmark			1	17
Estonia	1	39		
Finland	1	76	1	76
France	11	202	6	322
Germany	56	2,768	4	361
Greece			1	18
Hungary	4	188	1	32
Italy	7	209	2	144
Latvia	1	187		
Netherlands	5	280	2	127
Poland	14	1,445	1	11
Portugal	2	65	1	28
Romania			1	63
Slovakia	3	68		
Spain	4	206	3	349
United Kingdom	7	156	3	380
E.U.ROPEAN UNION	138	7,241	32	2,234
UNITED STATES[19]	35	1,305	15	2,079

[18] "Light Rail and Metro Systems in Europe," *ERRAC*, 2004, accessed July 26, 2011, http://www.errac.org/IMG/pdf/LRailandMetroinE.U.-042004.pdf.
[19] "Public Transportation Fact Book," *American Public Transportation Association*, 60th Edition, April 2009, accessed July 26, 2011, http://www.apta.com/gap/policyresearch/Documents/APTA_2009_Fact_Book.pdf.

In the United States, commuter service is typically operated by public transit authorities with diesel-electric equipment and trains will often share freight and intercity passenger lines for a fee. The commuter agency will purchase and maintain equipment and handle all ticketing and customer services. In some cases, the host railroad also functions as the contracted operator. Some commuter railroads have acquired separate rights-of-way for their high demand lines and this gives them more flexibility in scheduling trains during peak commuter travel periods. There are 22 commuter rail systems in the United States with a total length of 7,685 kilometers. Figure 2.13 shows a North Star train as an example of commuter rail that operates northwest of Minneapolis, Minnesota, U.S. and a commuter train from Helsinki, Finland.

Figure 2.14 - North Star Commuter Rail Train in Minneapolis, Minnesota, U.S. (Left) and commuter train in Helsinki, Finland (Right)

2.8 Rail Industry Employment

Table 2.9 below provides the best effort for quantification both in the U.S. and E.U. Because of the differences in the rail industry between the E.U. and U.S., it is difficult to provide a direct comparison on employment levels in the U.S. and E.U. However, even with limited data, it can be speculated that the overall size of rail industry employment is significantly higher in the E.U. than it is in the U.S. Statistics estimate that there are over 200,000 people employed directly by U.S. intercity passenger and freight railway companies. In addition there are almost 100,000 transit employees and another 150,000 working supply and manufacturing industry. For the estimates on employment supported by industry capital spending, the Association of American

Railroads used national multipliers for total economic output and jobs that result from that level of spending in the associated industry.

Table 2.9 - Railroad Employment by Region

Mode	European Union	United States
Urban Passenger Rail		97,624[20]
Passenger Rail (Amtrak)		20,500[21]
Freight Rail		184,000[22]
Freight Suppliers and Manufacturers		150,000[22]
Jobs supported by Rail Industry capital improvements		175,000[22]
Railway operators and related organizations	1,300,000[23]	
Total	**1,300,000**	**627,124**

The E.U. doesn't have similar categorizations of employer groups as the U.S. and their statistics didn't include information on urban mass transit. The number of people directly employed by railway operators is 1.3 million, based on official Eurostat statistics. Two problems arise, however, in relation to this information. First, the data available at the European level are incomplete and do not provide statistics on rail transport for all Member States. Second, these figures do not illustrate the development of employment in railway services accurately, taking into account the extensive restructuring of the sector, which has led to a more heterogeneous market structure, in which large rail companies have created separate divisions for different types of services and/or outsourced services to companies active in other sectors. In some cases, the state railways in Europe have also significant other operations outside rail transportation, such as buses or trucks. Another discrepancy that is apparent is between data from official statistical offices and those provided by the operating companies themselves and by other sources close to

[20] "Public Transportation Fact Book", *American Public Transportation Association*, 62nd Edition, April 2011, accessed July 26, 2011, http://www.apta.com/resources/statistics/Documents/FactBook/APTA_2011_Fact_Book.pdf
[21] "Amtrak, America's Railroad Annual Report FY 10", *Amtrak*, 2011, Accessed August 19, 2011, http://www.amtrak.com/servlet/BlobServer?blobcol=urldata&blobtable=MungoBlobs&blobkey=id&blobwhere=1249229514103&blobheader=application%2Fpdf&blobheadername1=Content-disposition&blobheadervalue1=attachment;filename=Amtrak_AmtrakAnnualReport_2010_v1.pdf
[22] "America's Freight Railroads, Supporting American Jobs, Moving the American Economy", *Association of American Railroads, 2011*, Accessed August 19, 2011, http://www.aar.org/~/media/aar/communications/railroadsjobs_final%20_3_.ashx
[23] "Employment, Industrial Relations and Working Conditions in the European Rail Transport Sector", *European Foundation for the Improvement of Living and Working Conditions*, Dublin, Ireland, 2006 (www.eurofound.eu.int)

the company level, such as industry associations. This makes it difficult to attain a clear and unambiguous picture of the development of employment in the past and of current employment levels[23].

One common factor between the U.S. and E.U. workforce is employee age which is higher than in other industries. Concerns over the increasing age of workforce in the U.S. were most recently raised in the Railroad Workforce Modal Profile which stated that in a span of seven years (1997-2004), the average employee age across the Class I railroads increased by nearly 10 years while the overall employee population decreased by almost 10,000 (Figure 2.15). In the United Kingdom, Project Brunel was established to address the same concerns on aging workforce.

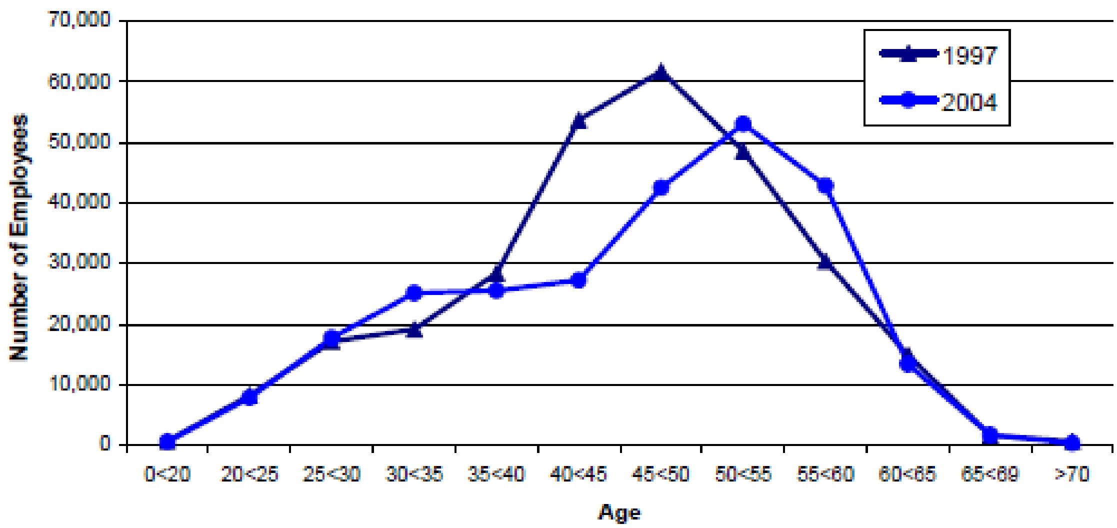

Figure 2.155 – Railroad Employee Age Distribution Shift in the U.S., 1997-2004

Figure 3. Railroad Employee Age Distribution Shift, 1997-2004 (SOURCE: RRB Annual Railroad Retirement Act and Railroad Unemployment Insurance Act data, statistical tables, section D: employment and compensation statistics, Table D-11, n.d.).

Even though the employment data obtained is incomplete and lacks possibility for direct comparison, it is evident that the total overall workforce related to rail transportation and related industries is significantly larger in the E.U. than in U.S. The actual magnitude of difference remains undefined, but the employment figures provide a good starting point when considering the demand for rail industry professionals and related rail higher education. These aspects are investigated in the following two chapters.

3 Inventory of University Rail Programs and Courses

3.1 Methodology

One of the objectives of the TUNRail project was to gather information on railroad transportation and engineering courses and programs from universities in both the U.S. and E.U. These data were obtained from universities with formal railway educational and/or research programs, as well as from universities that offer individual courses in railway transportation and engineering. The data collection effort focused primarily on engineering faculties and universities that specialize in higher-level education. As a result, data on universities that mainly concentrate on rail related research, on two-year associate degrees, short courses, and educational opportunities offered primarily to industry professionals were not included. The TUNRail project team recognizes the importance of such degrees in meeting the increased hiring needs within the railway industry, but benchmarking efforts of such programs were outside the scope of the current project. The chapter provides also short case studies of three programs in the U.S. and E.U. The illustrated programs are provided simply as examples to other interested universities and were selected solely based on the familiarity of research team with the programs.

Course and program data from U.S. universities were collected by an electronic survey in 2009 and 2010. The list of survey recipients was developed based on the TUNRail team's knowledge of existing programs and courses, as well as a list of professors that attended one of two Railroad Engineering Education Symposium (REES) training workshops aimed at encouraging processors to include railroad engineering content into their curricula. Courses that only have a small percentage of railroad-related content (i.e. an introductory transportation course with 10% of the course content devoted to rail) were not included in the survey data. Data from the E.U. were collected using survey templates that were distributed using e-mail inquiries to department heads or full professors responsible for development and inclusion of railroad transportation and engineering coursework in their curriculum. The course-level data were then compiled into summary sheets for each country.

Once all program and course data from the E.U. and U.S. were collected, they were categorized into program-specific and course-specific groups, to aid in comparing and contrasting the two approaches to railway transportation education. The following sections provide a summary of the data and include comparisons between E.U. and U.S. university course offerings and programs. Data from university railway programs and courses are included in Appendices A and B.

Although the TUNRail research team has attempted to develop a comprehensive inventory of U.S. and E.U. programs and courses, it is recognized that some academic institutions engaged in railway transportation research and teaching activities may not be included in the data. This is especially true in the E.U., where current levels of railway education and research in academia are considerably more extensive than in the U.S., making them more challenging to quantify. There is no central data source for such programs which made the data collection effort very challenging. There may also be weaknesses in the data set (in E.U. data) due to language barriers and other sources of potential inaccuracies (in both E.U. and U.S. data). In summary, the data used for this research were not verified and are presented on an "as-received" basis from the respondents.

3.2 U.S. Railway Programs and Courses

3.2.1 History

Two articles by Dr. Christopher Barkan provide an interesting synopsis to the history of rail higher education and related programs in the U.S.[24,25] In the 19th and early 20th century, U.S. railroads enjoyed strong relationships with the academic community and railroad courses were taught and rail-related research was conducted on campuses nationwide. Following World War II, these relationships began to fade. The rail industry's declining fortunes in the latter decades of the regulated era was one reason for the declining interest in railroad education in the U.S. Additionally, railroads began outsourcing many functions and new technologies were introduced, this resulted in a reduction in a need for new entry level engineering graduates. Although these changes were essential to the industry's financial survival and recent resurgence, one notable casualty was the nearly complete loss of a relationship with the academic community. Railroads curtailed much of their campus-based research programs and substantially reduced hiring of

[24] Barkan, C.P.L., "Building an Education Infrastructure for Railway Transportation Engineering: Renewed Partnerships on New Tracks", TR News, 2008 257: 18-23, Transportation Research Board of the National Academies, Washington, DC.

[25] Barkan, C.P.L. 2009. "Renewing the Partnership", Railway Age, October 2009: 25-26, Simmons-Boardman Publishing Corp., New York, NY.

university graduates. This neglect led faculty and college administrators to perceive railroads as an obsolete, possibly dying industry, with little relevance to society.

With the development of the Interstate freeway system in the United States in the 1950s, state and federal departments of transportation (DOTs) soon grew to rely on universities to conduct research and educate students to meet the burgeoning need for new talent in these fields. As aging faculty experts in railroad engineering retired, young faculty with highway transportation expertise moved in to replace them. A key ingredient of success for faculty and administrators is a strong, vibrant program of sponsored research so while railroads exited campuses, public- and private-sector highway transportation interests filled the void. Large amounts of funding were invested in educational programs and research on topics in highway transportation and these funding policies continue to this day.

The result is a close relationship between the organizations sponsoring highway research (Federal Highway Agency (FHWA), state DOTs, etc.) and the academic transportation community. Due to this, transportation faculty has become thoroughly invested in academic careers centered on highway-oriented research. This has affected course content as generations of students have been immersed in highways, to the near total exclusion of rail. The loss of rail-oriented research had a more insidious effect as in addition to losing the benefit of innovations that might have developed, it also fostered the impression that railroads were not interested in technological advances and this reinforcing the perception of railroad obsolescence.

Highway transportation engineering is a well-established element of the curriculum in the U.S. university programs. Nearly all major engineering programs teach introductory transportation engineering. However, despite having the word “transportation” in the title, the content of these courses is almost exclusively highway-oriented. In addition, many offer advanced highway engineering and transportation courses. It is not unusual for there to be up to half-a-dozen faculty whose expertise and research is focused on some aspect of highway transportation. The implications are profound, for society as well as for the rail industry. Besides the difficulty in finding graduates interested in railroad positions, transportation professionals at the local, state and federal levels also have little understanding of the railroads. When railroad projects arise, there is often poor understanding of the exigencies of railroad infrastructure and operations. Our nation’s over-dependence on highway transport and public resistance too many new rail projects is rooted in widespread ignorance about where, when, and how rail contributes to the nation's transportation needs. This is not surprising given the scarcity of rail content in current educational programs.

Recent growth and changes U.S. rail transportation suggest that a new course of action is needed. The freight rail renaissance will continue as the economy recovers, and expansion of passenger rail will continue. This will increase the need for expanded infrastructure and well-educated personnel to plan, design, build, operate, maintain, and manage all of these new activities. Rail infrastructure, rolling stock, and train control technology is at a dynamic stage. Accommodating new demands for safety, speed, service, capacity, sustainability, and energy efficiency require the best that industry, government, and academia have to offer. Innovative solutions are required and new talent is needed to apply new ideas and technologies. However, until recently, both industry and government have largely neglected the role of academia in helping rail transportation to fulfill its potential in the 21st century.

In addition to the rail transportation and engineering programs described in this chapter, the team identified that a few universities have research funding from Federal Railroad Administration (FRA) and other sources but they do not offer any courses in railroad engineering. Currently, there is roughly a 100:1 ratio of highway to rail academic funding in the U.S. The rail industry is accustomed to competing with the highway sector for traffic, but now it must also compete for faculty and students interested in transportation careers.

3.2.2 Existing U.S. University Programs and Courses

In 2010, there were two recognized railway transportation and engineering university programs in the U.S., with a third program projected to begin accepting incoming students in 2011. The research team defined a "program" as one that is engaged in teaching and research in the field of railway transportation and engineering and has officially defined its activities as a "program". A program will typically include a few courses and faculty with expertise in railroad engineering. The three railway programs are described in more detail in the following sections.

In addition to the inventory of university railway transportation programs, the research team also investigated specific, discrete railroad courses offered by universities involved in rail education. Currently, there are 20 courses in rail engineering and transportation listed in the U.S. (including passenger and transit courses). The number of courses at any specific university ranges from one to six, with only three universities offering more than two courses (as measured by listings in their course catalogue). Typical course enrolment varies widely, with graduate courses typically having fewer enrolled students than undergraduate courses (a trend that is visible in other transportation and engineering fields as well). Table 3.1 provides a summary of typical railroad course topics, enrolment numbers, and types of collaboration with industry in the U.S. A listing of universities with courses and related course details are provided in Appendices A-1 and A-2.

Table 3.1 - Summary of U.S. University Railway Transportation and Engineering Course Offerings

Description	Information
Example course titles	Railroad Track Engineering and Design Railroad Operations and Management Railroad Planning and Design Intermodal Freight Transportation Public Transit
Number (range) of students enrolled in courses	10-40 (undergraduate) 3-15 (graduate)
Average number of railway courses offered per year (total of all U.S. universities)	10
Examples of collaboration with the railway industry	Railway industry funding Sponsored research projects Official partnerships with financial support Internships Field trips for classes or railroad student chapters Development of classes Guest speakers

3.2.3 U.S. Case Studies

3.2.3.1 Rail Transportation and Engineering Center [RailTEC] (University of Illinois at Urbana-Champaign)

The University of Illinois at Urbana-Champaign (UIUC) is located in east central Illinois about 160 kilometers south of Chicago. The university was founded in 1867 and today there are over 30,000 undergraduate and 12,000 graduate students on campus. The College of Engineering is among the largest and highest ranked engineering colleges in the U.S., with twelve departments and over four hundred faculty members. The university has been a leader in rail transportation education and research for over a century and is committed to further growth and development of its engineering, teaching, and research activities in rail transportation. The center of rail transportation activities at UIUC is the Rail Transportation and Engineering Center (RailTEC) program in the Department of Civil and Environmental Engineering (CEE). The Director the program is Dr. Christopher Barkan and the web site for RailTEC is http://ict.uiuc.edu/railroad.

Currently, RailTEC offers six courses in railway engineering, transportation and operations, and plans to continue expanding with new course offerings in the future. The existing courses cover a variety of topics, including an overview of rail transportation and engineering, design of railway infrastructure, signaling and traffic control, high-speed rail engineering, railway capital project planning and design, and advances in railway technology. Students gain experience in rail freight, passenger, and transit engineering, operations, and management through a wide variety of courses taught by experienced faculty members, and hands-on experience gained in research laboratories and field visits to railway facilities. Faculty and students participate in regularly-scheduled seminars, short courses, workshops and conferences. UIUC also maintains the W.W. Hay Railroad Engineering Collection in the Grainger Engineering Library which is the largest collection of technical and engineering railroad books, reports, journals and other reference materials in North America.

Current and future RailTEC research interests include cutting-edge research in railway freight, passenger, and transit engineering. The broad range of research encompasses the full spectrum of rail transportation engineering, including work on topics such as: infrastructure and rolling stock engineering, safety and risk, energy efficiency and environment, operations research, planning and design, signaling and control, business and economics and advanced rail transportation technologies. RailTEC's research is sponsored by the Association of American Railroads (AAR), Railway Supply Institute (RSI), United States Department of Transportation (USDOT), United States Department of Education (USDOED), Transportation Research Board (TRB), railroads, railway supply companies and railway customers. UIUC is one of three AAR-affiliated laboratories and is fortunate to have several endowments from sources such as the CN Railway and George Krambles Transportation Scholarship Fund.

3.2.3.2 Rail Transportation Program - RTP at Michigan Technological University (Michigan Tech)

Michigan Technological University (also known as “Michigan Tech”) is located in Houghton, Michigan, in the Upper Peninsula of the state. It was founded in 1885 as a mining college to support the copper mines of the area but over the years it has grown to be a leading public research university which offers over 120 degree programs in engineering, business, forestry, arts and sciences, and technology. Today there are over 6,000 undergraduate and 1,000 graduate students on campus. The Rail Transportation Program (RTP) grew from an intensive five-week summer course offering railroad engineering and Finnish language and culture that included a week on the Michigan Tech campus, a week in Chicago and three weeks in Finland. The Summer in Finland (SIF) program was offered annually between 2004 and 2009; it was a great success with almost 100 students from several disciplines who participated in the program, including civil, environmental, electrical, mechanical, materials, construction management, engineering technology, and social science majors. Over 20 percent of the participants proceeded to rail industry internships after the program and an equal percentage has selected the rail industry for their post-graduate careers. The program became a foundation for further development of railroad activities at Michigan Tech culminating in the establishment of a Rail Transportation Program (RTP) under the Michigan Tech Transportation Institute (MTTI). Dr. Pasi Lautala is the Director of the program and the web site for rail transportation activities at Michigan Tech is www.rail.mtu.edu.

The objective of the Rail Transportation Program (RTP) is to make Michigan Tech one of the leading institutions of higher education providing railway-related education and research. Although the program development started from the educational side, the long-term emphasis is to balance the education and research activities. Currently, the program employs one full-time faculty and several others are involved in teaching and research activities.

In addition to the *International Railroad Engineering* course offered as part of the Summer in Finland program, three additional rail-related courses - *Public Transit* and *Track Engineering and Design* and *Rail Transportation Seminar*, are offered by the university. Several industry supported rail senior design and student enterprise projects have been completed over the past few years. The student roadmap for rail activities at Michigan Tech is presented in Figure 3.1.

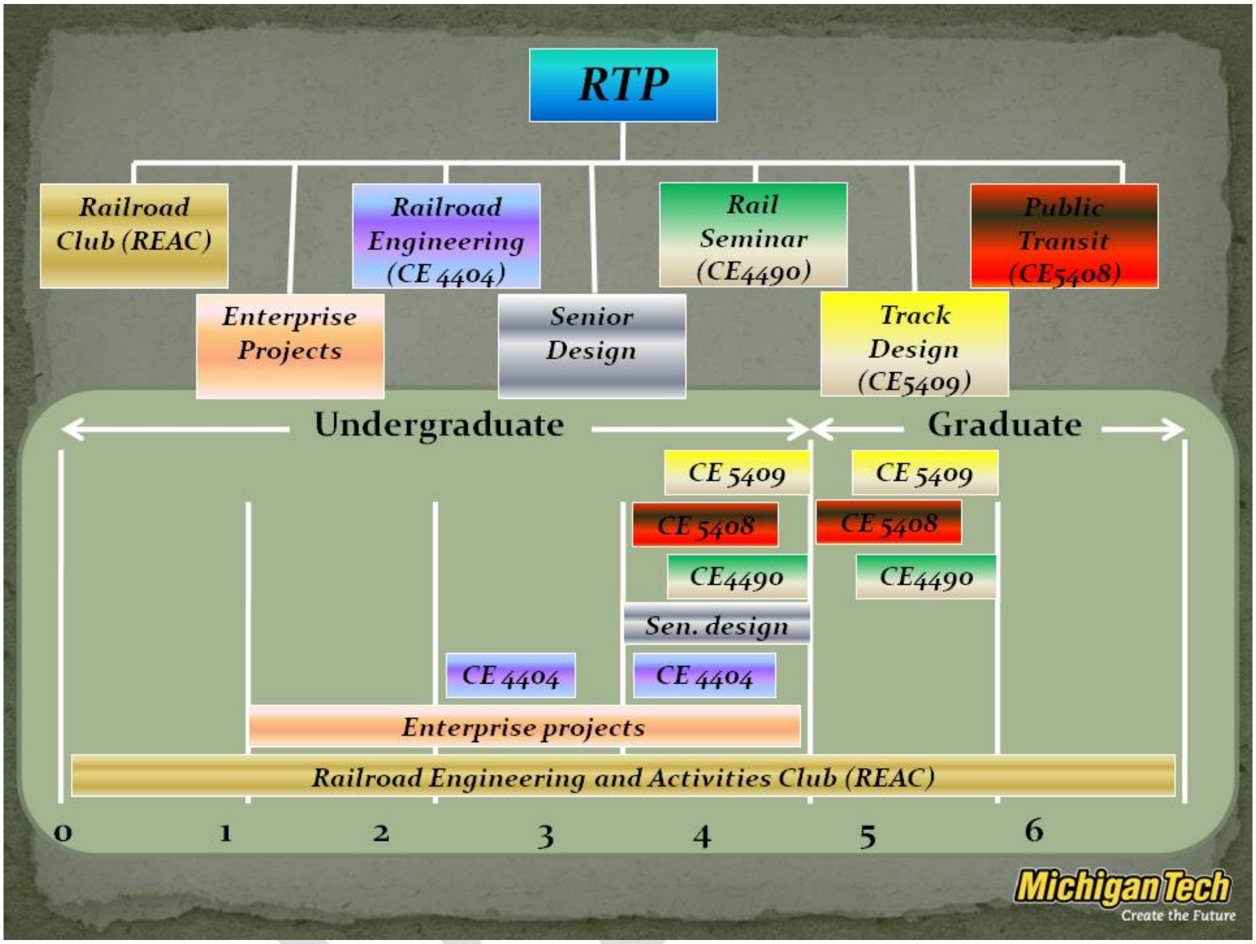

Figure 3.1 - The Development of Michigan Tech Rail Transportation Program Activities

Students from the first Summer in Finland program formed the Railroad Engineering and Activities Club (REAC) as an avenue to keep their enthusiasm in rail transportation alive. REAC was recognized as an official student organization and it became the first student chapter for the American Railway Engineering and Maintenance –of-Way Association (AREMA) in 2006. Today there are almost 60 members in the club from several departments. The objective of the club is "to organize and participate in events that increase the visibility of the rail industry on campus and in the community". Activities organized by REAC, such as industry guest presentations at monthly meetings and field visits to rail facilities, have quickly become the central avenue at Michigan Tech to attract students to the rail industry and to assist in industry recruitment. The highlight of REAC organized activities is the Railroad Night that annually gathers over 100 faculty, students, administration and industry for a social dinner to discuss rail transportation and related activities at Michigan Tech.

The activities had been developed in a close cooperation with the industry since the beginning, and companies have successfully recruited at Tech for several years. Since the formation of the RTP, the program has established three official industry partnerships with large freight railroads. These partners provide funding and other support, such as guest lecturers, and as a return are offered space and opportunities for promotional materials and events. In the future, the objective is to expand the partnerships for collaborative research and student projects and to build closer advising relationship between the program and industry. The program has also attracted several externally-funded research projects related to rail transportation.

There are several plans for further development of the program. One of them is to secure a significant endowment for the program that will function as a backbone of funding. On the educational side, the highest priority is the establishment of an undergraduate certificate in rail transportation engineering for students from multiple disciplines as well as the establishment of rail transportation seminar.

3.2.3.3 Rail Transportation Engineering Degree Program (Penn State Altoona)

Penn State Altoona was founded in 1937 and for many years earned associate degrees in several areas of study. In 1997, four year degree programs began and today over 4,200 undergraduate students are enrolled on campus. A degree program in Rail Transportation Engineering (RTE) has been developed and the first class of freshmen will begin studies in fall 2011. Students pursue a curriculum based upon civil engineering with a strong emphasis on courses related specifically to rail transportation. Eight new courses supply a strong industry specific background and topics include an industry overview, safety and operations, track design, signals/communications, mechanical systems, and a capstone design project. Students take three hands-on courses, called "practica," allowing them to work with real railroad equipment where they will use modern equipment to experience real-world train operations and they will work on the ground with track, locomotives, and the real problems of active railroading. The program also has several courses in business fundamentals including the history and regulatory structure of railroads, accounting, project management, and labor relations. Dr. Hai Huang is program co-ordinator and the RTE web site for more information is **www.altoona.psu.edu/rte**.

3.3 E.U. Railway Programs and Courses

3.3.1 History

The current situation of railway education in the E.U. is a direct result of the different political development over the past 50 years. Apart from the German-speaking countries where railway programs were established at many universities at the beginning of the 20^{th} century, programs in railway education were not important in Western Europe until the political changes of the early 1990s. Even in some of the larger countries (e.g. France or United Kingdom), university railway programs were practically non-existent. Typically, railways hired university graduates from general engineering programs, primarily civil and mechanical engineering, and placed them into trainee programs offered by the railways. In some countries, these railway trainee programs took several years and included comprehensive courses and examinations. Some railways established extensive academies for that very purpose and the teachers were experienced railway engineers on a part-time basis. In mid-1990s, the liberalization of the European Union railways led to a rapid fragmentation and commercialization of the industry. The new competitive environment led the newly specialized operators to seek options for reducing costs and, consequently, the in-house training programs were soon abandoned. Instead, they started looking for professionals in the market and at the universities. This demand resulted in a growing interest by the universities and, soon, multiple courses and programs have been launched.

In Eastern Europe, the situation was quite different. After World War II, countries adapted the Russian model of having highly-specialized universities and colleges (sometimes referred to as the 'academy model'). There are still several dedicated railway universities in Russia. Although Eastern European countries did not follow this approach of dedicated railway universities, they did establish transportation universities and colleges where higher transportation education was concentrated. Typical examples are the transportation colleges in Dresden (East Germany), Žilina (Czechoslovakia), Györ (Hungary), and Sofia (Bulgaria). In Poland and Romania, transportation departments were installed at existing technical universities and cooperation was established with the national railways to produce 'ready-to-run' railway engineers that could begin their railway jobs directly after graduation without the need for additional training. For these reasons, the East European railways never established extensive training programs like their Western counterparts.

In the 1990s, after the end of the Soviet empire, some East European countries maintained this model while others did not. In Dresden, the former college of transportation became a department of the Dresden Technical University and it still offers a comprehensive railway program. The transportation colleges in Žilina (now Slovakia) and Györ were transformed into general universities without a specialization in transportation. In Romania and Bulgaria, comprehensive railway programs still exist.

Despite all of the changes over the last two decades, a uniform system of higher railway education does not exist in Europe and there are still many significant differences between countries and groups of countries.

3.3.2 Existing E.U. Programs and Courses

The research team collected data on 37 university railway programs with 260 railway courses in 14 countries across Europe. We acknowledge that this is not an exhaustive list, yet we believe it is representative of the European reality. The database was summarized and is presented in Appendix B-1. Based on the data, the following observations can be made:

- The largest number of university railway programs is found in the German-speaking part of Europe where for more than 100 years, railway engineering has been a regular part of the curriculum in civil engineering and transportation engineering. About 45% of the railway courses in the E.U. are offered in the German-speaking part of Europe.
- In some Western European countries, specific university education in railways is rare. While research work is being undertaken in rail transportation, course work in railways has not been common.
- While the total number of university railway programs in East European countries is quite low, the existing programs are very comprehensive with an impressive number of courses offerings. Both the number of enrolled students and the number of teaching staff involved in railway education is much greater than in any Western European country.

Figure 3.2 shows the subjects or topics covered in E.U. railway courses. Railway infrastructure, operations, and rolling stock are the most popular subject areas. A listing of courses, by country and teaching subject or topic area are included in Appendix B-2.

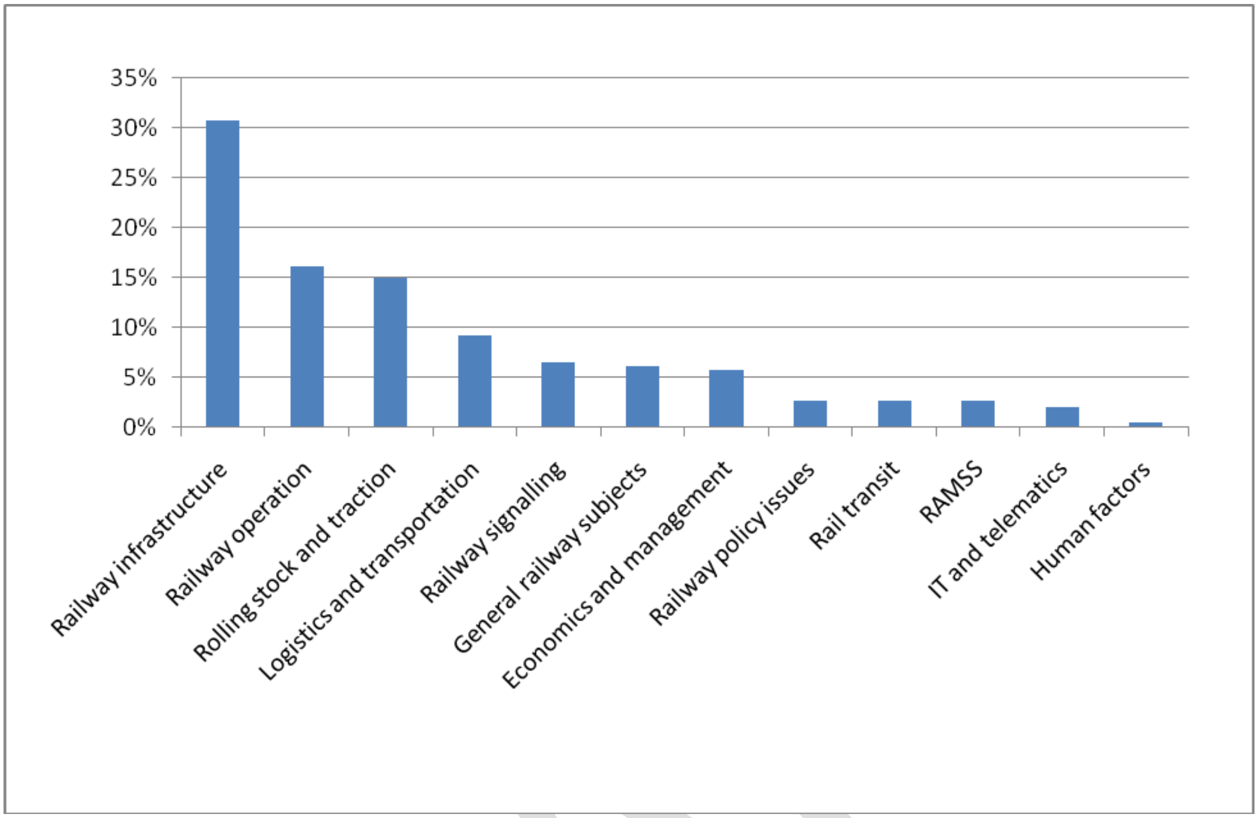

Figure 3.2 - Subjects Covered in E.U. Railway Courses

The percentages presented in Figure 3.2 are calculated by considering the number of courses, but not the differences in the number of credits and lecture hours. It is assumed that these differences are equalized by the large number of courses, so that the results will not differ significantly from a more detailed analysis. There is also some uncertainty in assigning the courses to teaching subjects. With very short descriptions of the contents and in some cases not much more than the course title the decision on what subject a course must be assigned to was sometimes based on an informed assumption. Here, as before, it is also assumed that the large number of courses will equalize these uncertainties. The subject 'General railway issues' was created to cover both introductory courses that provide an overview on the railway system, as well as more specialized courses dealing with several aspects of specific rail systems (e.g. industrial railways).

The leading teaching subject in European railway education is railway infrastructure, with a share of almost one-third of all courses. It is followed by railway operation and rolling stock issues. The percentages between topic areas represent the total of all courses, but not necessarily the typical structure of an individual rail program. However, it does provide a good picture of the relevance of different teaching subjects in Europe. The share of teaching subjects in an individual railway program depends on whether the program is more infrastructure or rolling stock-oriented. In infrastructure-oriented programs, there are also differences between programs that are more construction related and programs that concentrate more on operation and signaling. A summary of E.U. railway transportation and engineering course offerings is shown in Table 3.2 below.

Table 3.2 - Summary of E.U. Railway Transportation and Engineering Course Offerings

Description	Information
Example course topics	Railway Operations Management Railway Signalling Transportation Economics Railroad Vehicle Engineering Operation of Railroad Vehicles Railway infrastructures
Number (range) of students enrolled in courses at each university	20-200 (undergraduate) 10-20 (graduate)
Average number of railway courses offered per year (total for all E.U. countries)	260
Examples of collaboration with the railway industry	Railway industry funding Sponsored research projects Official partnerships with financial support Internships Field trips for classes Guest speakers / professors from industry

3.3.3 E.U. Case Studies

3.3.3.1 Technical University Braunschweig

German universities offer two types of railway engineering programs. There are programs that focus on infrastructure design and operation, including train scheduling and dispatching, and the second type are those that focus on railway vehicle design. This also mirrors the current separation of the railway industry into infrastructure managers and train operating companies. The largest needs are for graduates in the infrastructure area and this is the reason that more infrastructure oriented programs are offered. Only about 30% of these universities offer a rolling stock-oriented program. An excellent example of a railway program in infrastructure is offered at the Technical University Braunschweig.

Technical University Braunschweig (www.tu-braunschweig.de) was founded in 1745 and it is the oldest university of technology in Germany. Today there are over 13,000 students at the university. The railway program was established in the late 1950s following a tradition of teaching railway issues for civil engineers that began in the late 19th century. The need to develop the traditional railway courses into a new program was caused by the increasing role of signaling and automation technologies for rail traffic control. As a result, traditional civil engineering subjects were combined with aspects of electrical engineering but as the use of computer technology increased, electrical engineering topics were often replaced by those focused on the use of software technology in railway signaling and operations control. The research activities are being undertaken by researchers who are not as involved in teaching and their positions are funded by research contracts with external partners.

Railway courses are offered for students from several departments including civil and environmental engineering, mobility and transportation (Braunschweig term for transportation engineering), computer science, and business engineering.

Among the undergraduate courses offered for all of these programs include Railway Infrastructure, Railway Operations Technology, and Railway Infrastructure for Environmental Engineers. In civil engineering, mobility and transportation, and business engineering, enrollment in a portion of these classes is compulsory. The class with the largest number of attendees is the basic course in railway infrastructure, which is compulsory for all of these students. The number of students in this class may easily exceed 200. Students of environmental engineering take a separate course on railway infrastructure. Apart from environmental engineering, students from each of these study programs can also enroll for graduate-level railway courses. Graduate classes for students of environmental engineering are not yet available, but are being planned for the future. Currently, the following graduate courses are offered: Guided Urban Transportation Systems, Railway Infrastructure Design, Railway Operations Management, and Railway Signaling.

Each German university railway program typically has a specific subject in which teaching is more comprehensive than at other universities and this is usually a function of the research activities that are underway at the university. In Braunschweig, this subject is railway signaling. Since Braunschweig is also the home of the Siemens signaling department, excellent opportunities are available for cooperation with the signaling industry and Siemens even supports academic teaching by funding a Ph.D. program in the field of railway signaling and automation.

In the railway graduate courses, the typical enrolment is 10 to 20 students. However, since most students in the graduate railway courses also enroll for non-railway-related courses, only a portion of the graduates (on average 5 to 10 students) finally join the railway industry.

In most German university railway programs, aspects of railway operation play a central role. For practical training, railway operations laboratories are widely-used. Braunschweig University does not own a railway operations laboratory. These extremely expensive facilities (not only from a financial standpoint, but also because of space requirements) only exist at selected universities and are commonly used on a contract basis. For the university's railway program, the Berlin Railway Laboratory is used but because of frequent high speed train service between Braunschweig and Berlin, the Berlin laboratory can be conveniently used without staying overnight. Students enrolled for the courses in railway signaling or railway operations management spend at least one full laboratory day in the Berlin facility, in order to receive training in railway operation processes and the working of different signaling systems.

3.3.3.2 Universidade Técnica de Lisboa (IST – UTL)

The railway education in Portuguese higher education institutions is concentrated in the Schools of Engineering and, in particular, in the programs of Civil Engineering and Mechanical Engineering.

Among the Portuguese Schools of Engineering, the most well known are the Instituto Superior Técnico of the Technical University of Lisbon (Lisbon), the Faculty of Engineering of the University of Oporto (Oporto), the Faculty of Science and Technology of the University of Coimbra (Coimbra), and the School of Engineering of the University of Minho (Guimarães).

Enrollment numbers depend on the University, but are usually 100 to 150 students in the Civil Engineering programs and 80 to 120 in the Mechanical Engineering programs.

The typical engineering program is five years and it is divided in two time periods. The first four years is referred to as the Common Branch and it includes a comprehensive set of compulsory courses for all students. The fifth year is referred to the Specialization Branch and it includes compulsory and optional courses on a specific topic specialization domain. For example, in civil engineering, the typical specialization domains include structural design, construction, geotechnics, transportation and planning. There are three types of railway courses in a typical engineering program.

- Compulsory course in the Common Branch – typically it is an introductory course on transportation, where railways are included.
- Compulsory course in the Specialization Branch – typically a course (semester or annual) dedicated to railways.
- An optional course in the Specialization Branch– typically it is a course (semester or annual) entirely dedicated to the railways, but it is usually less demanding since it is an optional course available to students of other specializations.

Most civil and mechanical engineers in Portugal have some background in railways, and some have considerable expertise so the specific qualifications depend on the course and the program. The Civil Engineering Program at the Instituto Superior Técnico of the Technical University of Lisbon (www.utl.pt) has two courses related to railway education – Transportation (third year, compulsory course, common branch) and Railway Engineering (fifth year, optional course, specialization branch). The contents of the Railway Engineering course include:

- Introduction to railways engineering:
    - Competition in rail transport systems;
    - Fundamentals of the operation and management of infrastructure and rail services; and
    - Fundamental concepts of railroad and rolling stock.
- Infrastructure and rail structure:

    - Tracing;
    - Vehicle-track interaction;
    - Switches and crossings;
    - Maintenance costs;
    - Optimization of design of high speed rail; and
    - Criteria for the design of railway bridges and tunnels.
- Operation and exploration:
    - Carrying capacity and characteristics of materials (power, resistance, braking);
    - Carrying capacity of fixed installations (electrification, signaling, operating systems); and
    - Planning of rail services (planning of train movements, scaling stations, strategic planning of rail services).

An exciting era for Portuguese railway education has occurred through a partnership with the Massachusetts Institute of Technology (MIT) and the Portugal Program (MPP). The MPP is a large-scale international collaboration involving MIT and government, academia and industry, aimed to develop education and research programs related to engineering systems. The five-year program started in 2006 and negotiations are currently underway for the renewal of the contract.

The MPP has five areas in the partnership - transportation systems, bioengineering systems, engineering design and advanced manufacturing, sustainable energy systems, and engineering systems program. The focus of the MPP Transportation Systems area is the design of complex, large-scale systems that have major societal impact and provide opportunities for sustainable economic development, and the goal is the development of transportation researchers and professionals in Portugal who are trained at the system level in the design and management of a technology-intensive, intermodal transportation systems. In addition, the Transportation Systems focus area aims to establish a collaborative, in-depth research program, building from the comparative advantage of the universities and researchers involved.

The education component of the MPP includes the Complex Transport Infrastructure Systems (CTIS) master level program and a joint doctoral program in transportation, both including three Portuguese universities (Instituto Superior Técnico – Technical University of Lisbon, Faculty of Engineering – University of Oporto, and Faculty of Sciences and Technology – University of Coimbra). There are no specific courses on railways, although several courses cover topics related to railways (for example, transport economics, financing of infrastructure, and operations research). In addition, students can choose a research topic on railways when developing their master's thesis, provided they find a supervisor and co-supervisor willing to support it. The supervisor is a professor from one of the Portuguese universities and the co-supervisor is a professor from MIT.

The doctoral program is typically four years. In the first year the student takes a set of master and doctoral level courses, chosen from a pool of courses of the three Portuguese universities. In the subsequent years, the student develops a research topic. As with the CTIS master course, the supervisor is a professor from one of the Portuguese universities and the co-supervisor is a MIT professor. As part of the doctoral program, the student will spend three to twelve weeks at MIT as a visiting researcher. Four priority areas in transportation have been identified for this program - high speed rail (HSR), airports, intelligent transport systems and integrated transportation systems.

3.3.3.3 "Todor Kableshkov" Higher School of Transport (VTU), Sofia, Bulgaria

Railway higher education in Bulgaria has been concentrated in two Higher Education Institutions (HEIs): the Technical University of Sofia and the Higher Military Railway School "Todor Kableshkov". The railway courses offered by the Technical University of Sofia have been considered as a specialization rather than a separate railway engineering program and these courses have focused mainly on railway infrastructure and network design.

The Higher Military Railway School "Todor Kableshkov" was founded in 1922 for the purpose of training and creating professionals for the needs of the Bulgarian Railway Industry. Its activities have been carried out in close collaboration with the Bulgarian State Railways. The national military regime has been employed by the school, and the education process is supported by military officers and a majority of trainees are cadets. The School has several departments:

- Technology, Organization and Management of Railway Transport
- Telecommunications and Rail Signaling Systems
- Construction of Railway Infrastructure and Maintenance
- Railway Rolling Stock: Locomotives, Engines, Wagons
- Railway Economics, Pricing and Accounting

Each department offers a railway program within its scope, meaning that the five separate railway programs covered all the aspects of the railway system. For each railway program, typical annual enrolment was 30 cadets and 10 students. A mandatory internship course was included in the railway education programs and students and cadets have been placed in the Bulgarian State Railways working with the railway personnel on real-world projects. Following graduation, the graduates were given positions by the Bulgarian State Railways.

In addition to the academic portion, the school has provided opportunities to receive practical railway qualifications in such careers as:

- Train-traffic control manager
- Conductor and ticket inspector
- Shunter of freight trains
- Head of commercial operation in railway transport
- Train dispatcher
- Locomotive driver (electric and diesel)
- Wagon inspector
- Driver and mechanic of railway infrastructure building and maintenance machines

The School is equipped with Railway Transport Operation Laboratory Complex (RTOLC). The complex has recently received significant interest from the National and International Associations of Railway Model Makers. It has an area of 1600 square meters and consists of eight laboratory rooms equipped with control systems and interlocking devices. Passenger stations, marshalling yards, junctions, intermediary stops and depots are well-prototyped. It is worth noting that within the complex there is also a traffic safety and security laboratory.

Figure 3.3 - Railway Transport Operation Laboratory Complex in "Todor Kableshkov" Higher School of Transport (VTU), Sofia, Bulgaria

In September 2000, the Higher Military Railway School was demilitarized and renamed "Todor Kableshkov" Higher School of Transport and since that time, the mission of the school has changed. Today, the goal is to train and create professionals for the needs of the entire transport sector as well as telecommunications.

3.4 U.S. and E.U. Railway Program and Course Comparison

There are a wide variety of railway transportation and engineering courses available. The E.U. has dozens of railway programs, with a high percentage of programs located in the predominantly German-speaking regions. Teaching and research in railways are always closely linked at E.U. universities but there are only two programs in the U.S. that have both railway research and teaching activities. There are several universities in the U.S. where railway research is being conducted but there are no railroad courses being taught at the university. Table 3.3 provides a comparison of U.S. and E.U. universities with railway programs, railway research, or other railway academic outreach and teaching activities. However due to the large number of universities with rail activities in the E.U. (but without any official railway transportation and engineering programs), developing a more accurate estimate of those universities was beyond the scope of the TUNRail project. Informational data from the US and E.U. university rail programs and courses are included in Appendices A and B.

Table 3.3 - Summary of US and E.U. Railroad Transportation Education and Research Programs and Individual Railway Course Offerings (Note: some numbers are approximations)

Description	US		E.U.	
Number of universities with railroad programs (research and teaching combined)	2		21	
Number of universities with railroad research activity	19		---	
Number of universities with railroad courses	12		---	
Number of railroad courses offered	19		260	
	Range	**Average**	**Range**	**Average**
Number of faculty and staff at each research institution	1-6	3*	3-50	10
Number of graduate students engaged in railway research	4-14	7.5	5-20	10
Number of undergraduate and graduate students enrolled in railway courses	3-15	5.6	20-200	100
Number of railroad courses offered per university teaching railroad transportation	1-6	1.8	5-20	10

When reviewing the courses and course content at E.U. and U.S. universities, one the large number of courses in railroad engineering and transportation that are available at E.U. institutions when compared to U.S. universities becomes evident. In terms of rail engineering course content, the limited U.S. university courses tend to concentrate more on introductory and rail infrastructure related courses , whereas the E.U. offers more courses in the facilities and systems area of rail engineering.

It is important to note that the majority of students receiving a degree in civil engineering in the E.U. will obtain some level of education in the field of railways. However, this is not the case in the U.S., where it would be unique for a student would receive any rail education as part of a traditional civil engineering curriculum. There are currently no known examples in the U.S. where an undergraduate student in electrical engineering undergraduate student would receive any railway signaling and operations knowledge as part of their undergraduate curriculum.

The total number of students receiving rail education per year is approximately 150-250 in the US and 1,000-3,000 in the E.U. The larger number in the E.U. is due to the fact that at many universities, rail education is compulsory for all students of civil and transportation engineering. At the graduate level, the number of E.U. students receiving rail education is about 200-400 while in U.S. it is limited to a couple of dozen students. In recent years the interest in rail education and course offerings at U.S. universities has grown due to an awareness of the importance of the rail industry, and career opportunities. To assist university faculty who were not as familiar with the rail industry the Railroad Engineering Education Symposium (REES) has been offered twice in the past few years to provide an introduction to railway engineering and course materials. These symposia have resulted in additional course offerings and the inclusion of rail transport content into existing courses.

Since university rail education has been well-established for decades in the E.U., there is no general trend towards further growth. However, a shift has taken place from East to West Europe. In some Eastern countries, there are still comprehensive rail programs that were developed in the communist era when the railroad was still the most important means of transportation. It is to be expected that these programs will be reduced to a level that meets the needs of the current rail system. On the other hand, in several Western European countries, new university rail programs have been established as a result of the reformation process of European railroads. Since railroad companies are no longer willing to run extensive training programs for newly-hired college graduates, universities are expected to provide the necessary introduction and training.

4 Demand for Railway Higher Education and Competence Gap Analysis

4.1 Industry Survey

One of the objectives of the TUNRail study was to identify both quantitative demands and qualitative preferences placed by industry for graduates entering the rail industry. To achieve this goal, a targeted online industry survey of industry professionals was conducted. Several organizations and associations were used to assist in distributing the survey. The main distribution channels are presented in Table 4.1.

Table 4.1 - Key Distribution Channels for Industry Survey

US	E.U.
American Railway Engineering and Maintenance of Way Association (AREMA)	NewRail Professionals database by University of Newcastle upon Tyne (1,500 members worldwide)
American Association of Railroad Superintendents (AARS)	Universidade Técnica de Lisboa (IST) Professional Database, (approximately 1,000 contacts)
Railway Equipment, Manufacturer and Supplier Association (REMSA)	Linked In Professional Networks: (Railways Professional Group and Railway Signalling & Telecommunication Professional Group)
Michigan Tech University and University of Illinois – Urbana – Champaign rail industry mailing lists	Deutsche Bahn (German Railways)
	Verband Deutscher Eisenbahnigenieure VDEI (Association of German Railway Engineers) Verband der Deutschen Bahnindustrie VDB (Association of the German Railway Industry) Verband Deutscher Verkehrsunternehmen VDV (Association of German Transportation Companies)

The industry survey consisted of two parts. The first part was targeted at all rail industry professionals to help in understanding their background, their paths to the industry, and their opinions on the importance of university participation on the field. The second part was targeted for managers of younger professionals and those involved in recruitment and training. The structure of the industry survey is illustrated in Figure 4.1.

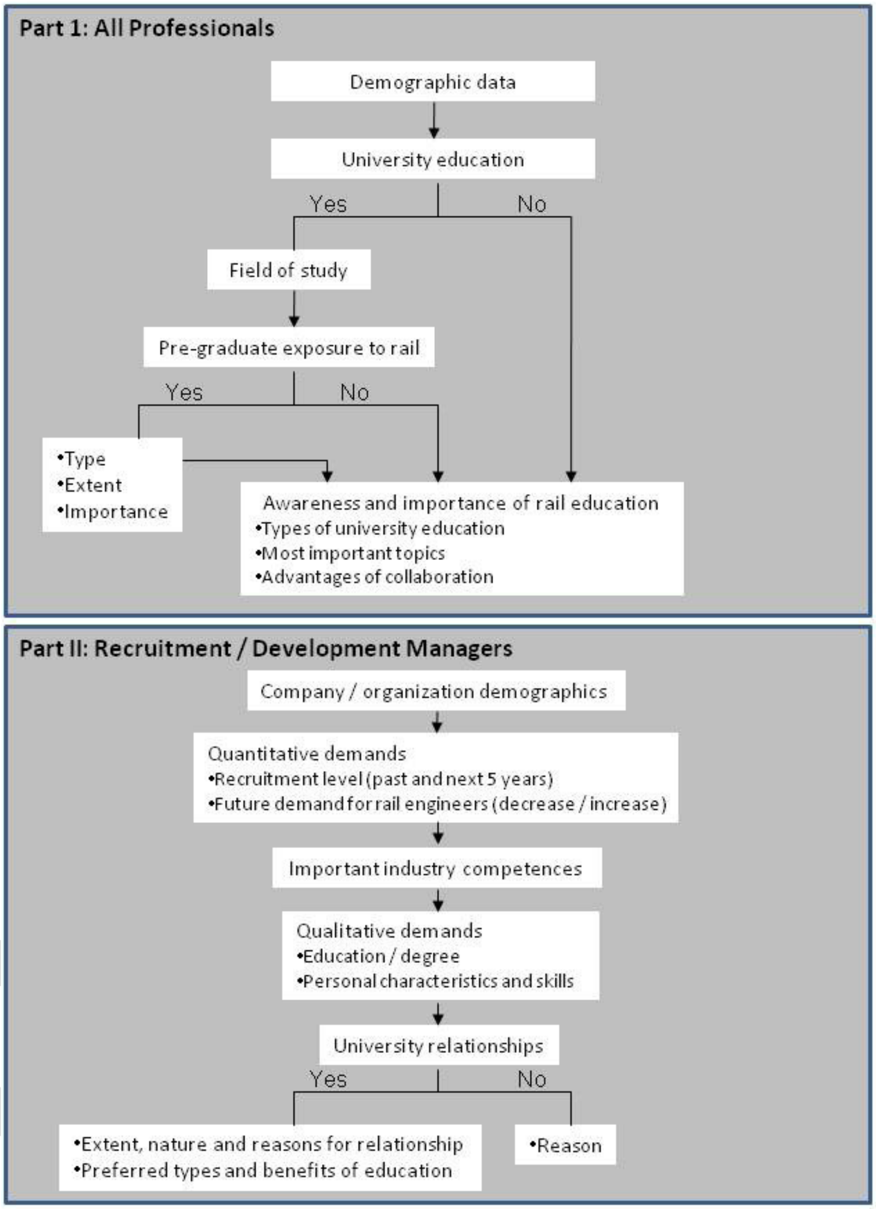

Figure 4.1 - Structure of On-Line Industry Survey

4.1.1 Survey Part I – All Professionals

Part I of the industry survey was completed by almost 600 respondents. The following sections provide summaries of survey responses. The complete list of survey questions can be found in Appendix C.

Figure 4.2 shows that the majority of respondents were males which are consistent with the industry demographics. It also reveals that 60% of the respondents were from U.S., 25% from E.U. and 15% from other geographic areas. Males were the largest group of respondents. While the survey was concentrating on the U.S. and E.U., several professionals from outside these geographic areas also completed the survey and provided an interesting perspective. One of the reasons for lower participation from E.U. participants was attributed to the difference in industry policy for completing surveys. In the E.U., companies often assigned responding to a survey to certain employee (or employees), while in U.S. the responses are not coordinated and reflect the personal interest and views of those who completed the survey.

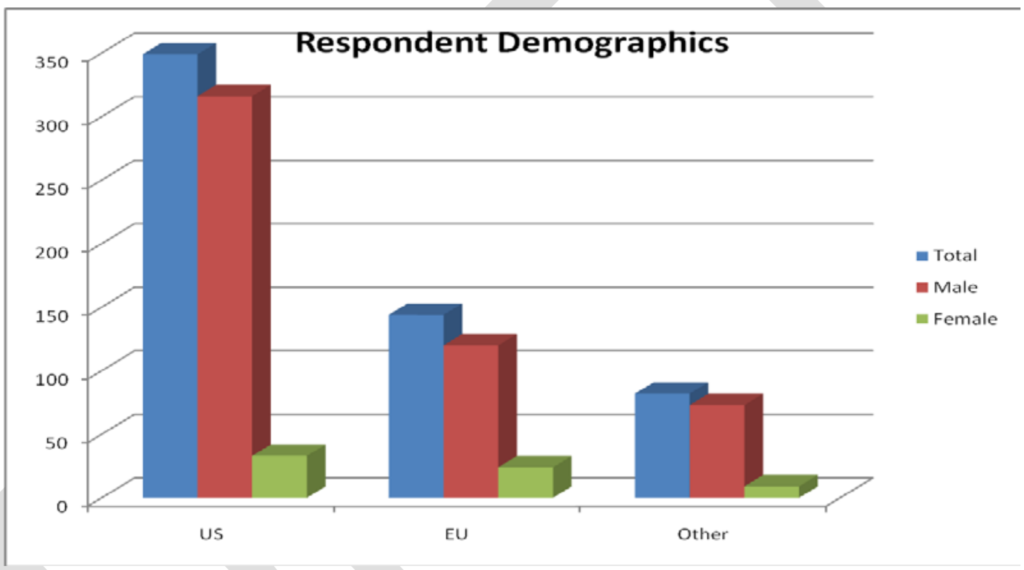

Figure 4.2 - Demographics of Survey Respondents

Figure 4.3 show the predominant location of the respondent's company. Almost half of the responds were from people who were employed by companies that primarily operated in North America, but it was recognized that several respondents were employed by companies with worldwide presence.

The educational background of respondents is provided in Figures 4.4 and 4.5. Almost half of the U.S. respondents had an undergraduate (BS) degree while there are a higher percentage of those from the E.U. that have earned graduate degrees (MS and PhD). Civil Engineering is the major area of study for U.S. respondents while mechanical engineering and other are the major background areas for E.U. respondents.

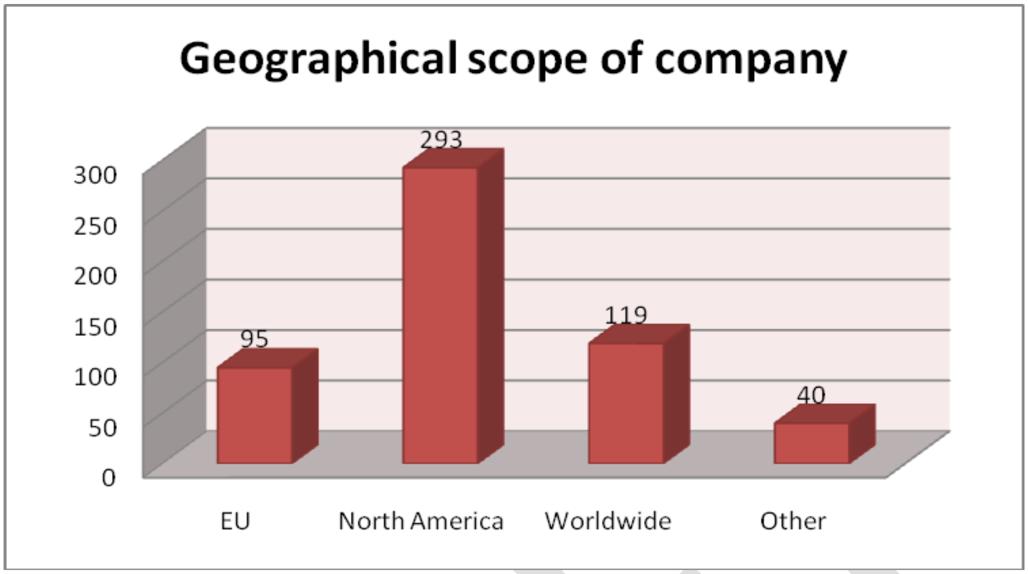

Figure 4.3 - Geographical Scope of Respondent Companies

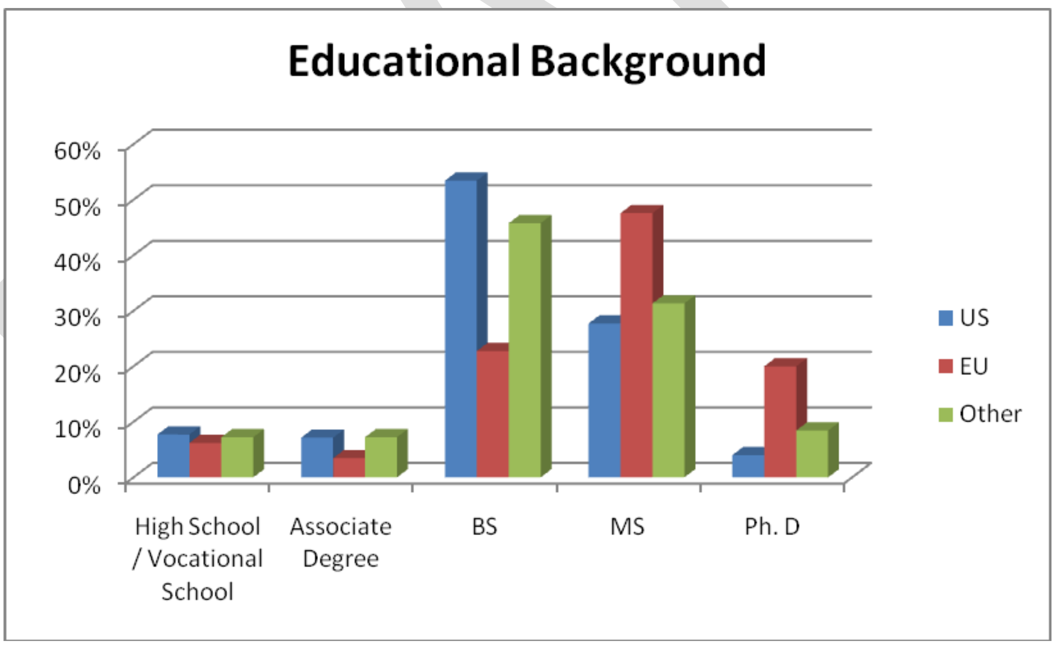

Figure 4.4 - Educational Level of Respondents

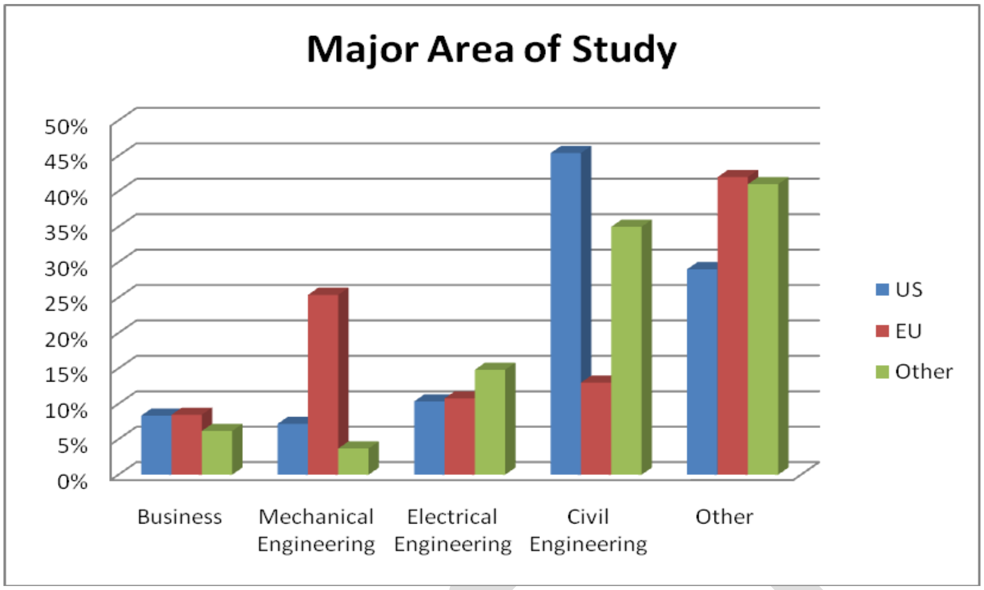

Figure 4.5 - Respondents' Majors

For the question on prior exposure to the rail industry, the majority of respondents did not have exposure to rail topics either prior to or during their university studies (Figure 4.6). Respondents from U.S. had slightly more exposure to the rail industry before they entered university, while respondents from E.U. had more exposure while university.

Figure 4.7 shows the positive effect of exposing students to the rail industry while in university. Most of the respondents said that exposure to the rail industry during their education played at least a minor role in their career decision. This is especially true in the US, where over 85% of respondents felt that exposure to rail industry while they were at university played a minor or major role in their career decision.

The survey then tried to determine the types of exposure to the rail industry while at university and Figure 4.8 and 4.9 shows the variety of approaches in the U.S. and E.U.. There is some variation between types of exposure in the U.S. compared to the E.U., but in general professional courses, subjects or topics in an undergraduate program, or full semester courses were the most common types of exposure.

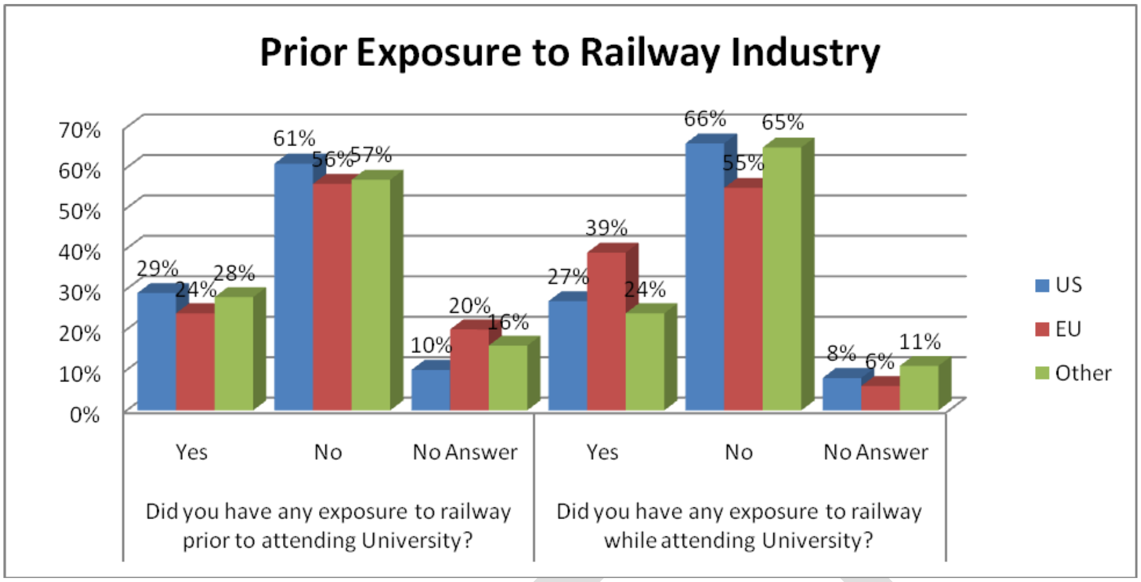

Figure 4.6 - Exposure to Rail Prior to or During University

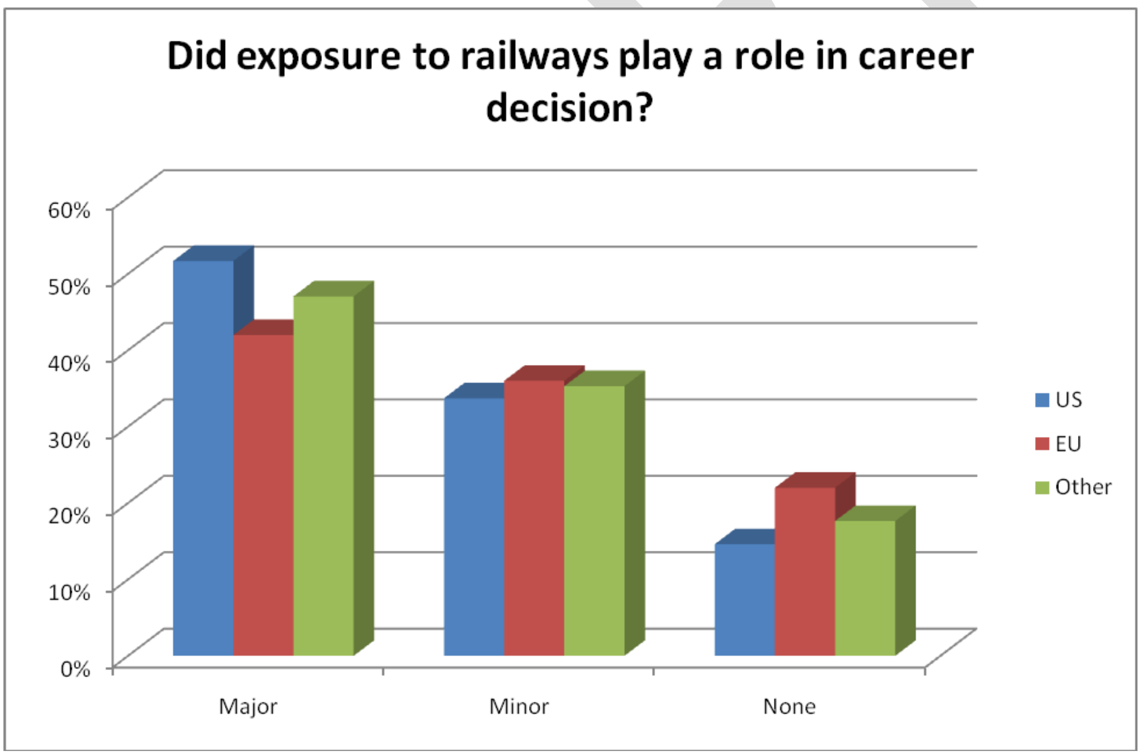

Figure 4.7 - Career Decision from Exposure to Railways

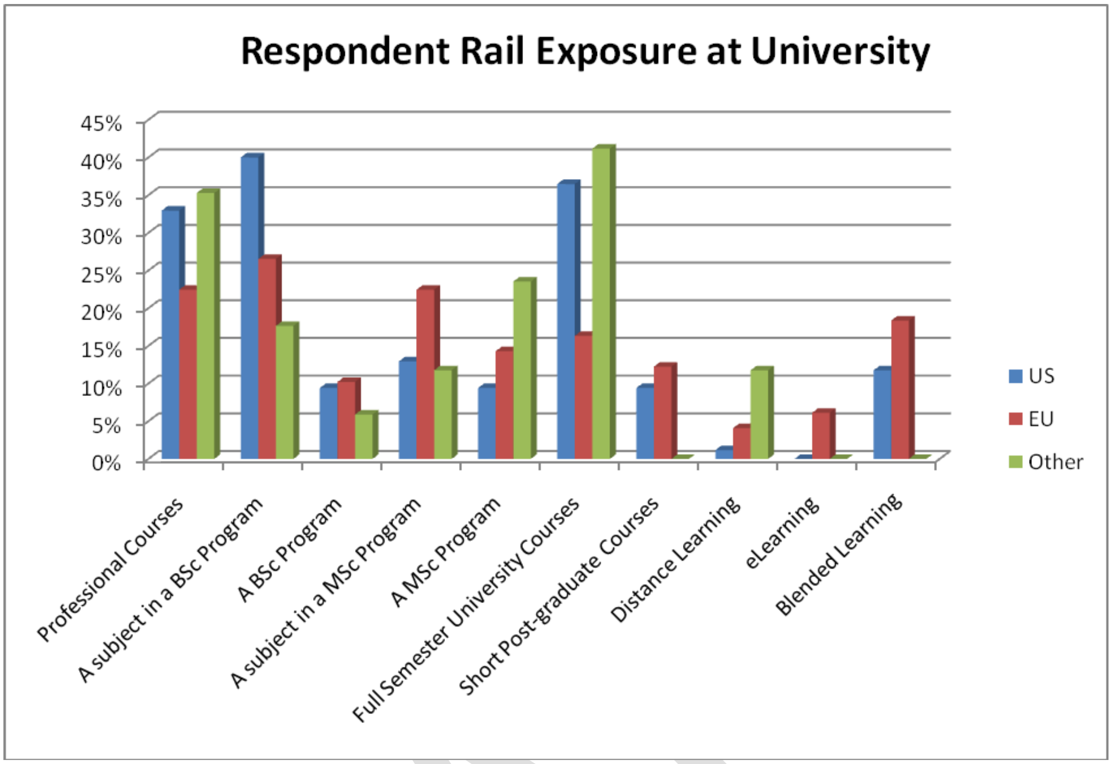

Figure 4.8 - Rail Exposure at University

Figure 4.10 shows a clear discrepancy between the U.S. and E.U. on the opinions of how well current university courses address the needs of the rail industry. Over 50% of E.U. respondents felt that current university courses are adequate for addressing key industry competencies. However, respondents from both the US and other geographic areas feel that current courses were inadequare for their needs.

Over half of the respondents noted that their organization was collaborating with universities and almost all respondents were unanimous on the benefits of a Trans-Atlantic collaboration (Figure 4.11). There is much a higher level of collaboration on research and project activities between industry and universities in the E.U.. The collaboration in the U.S. is more focused on internships and co-operative programs for students and guest speakers (Figure 4.12).

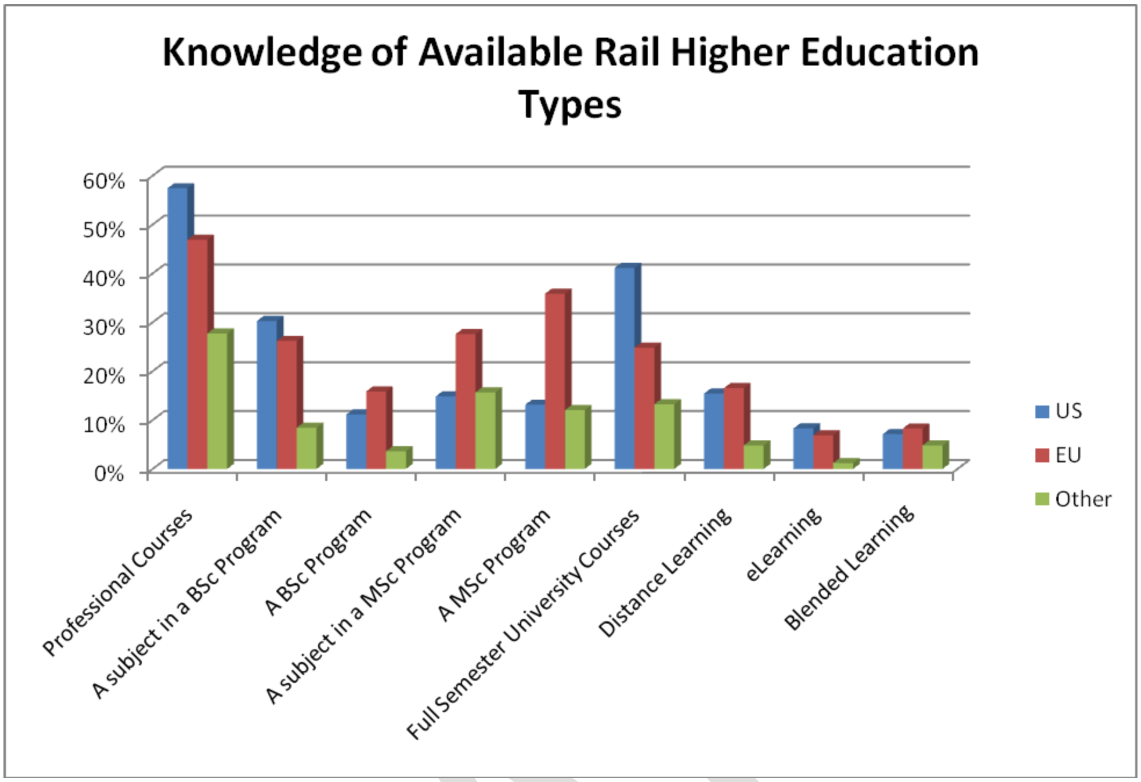

Figure 4.9 - Known Rail Education Offerings

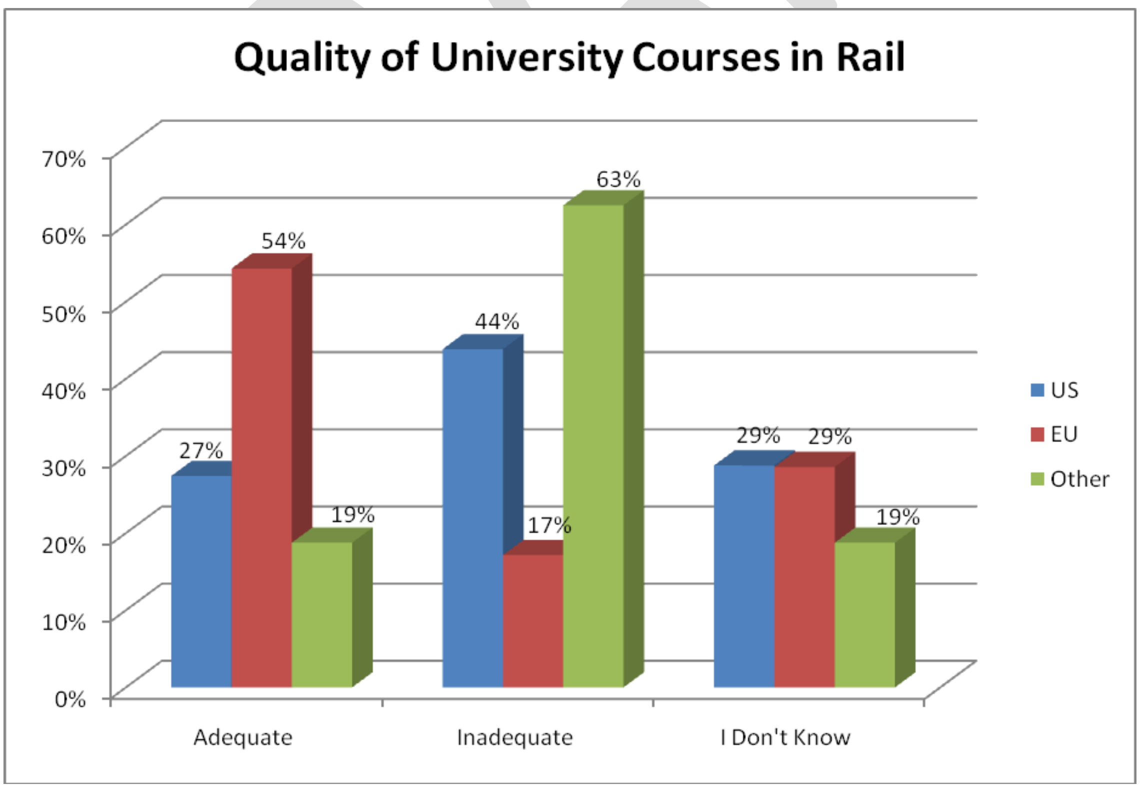

Figure 4.10 - Quality of Rail Courses

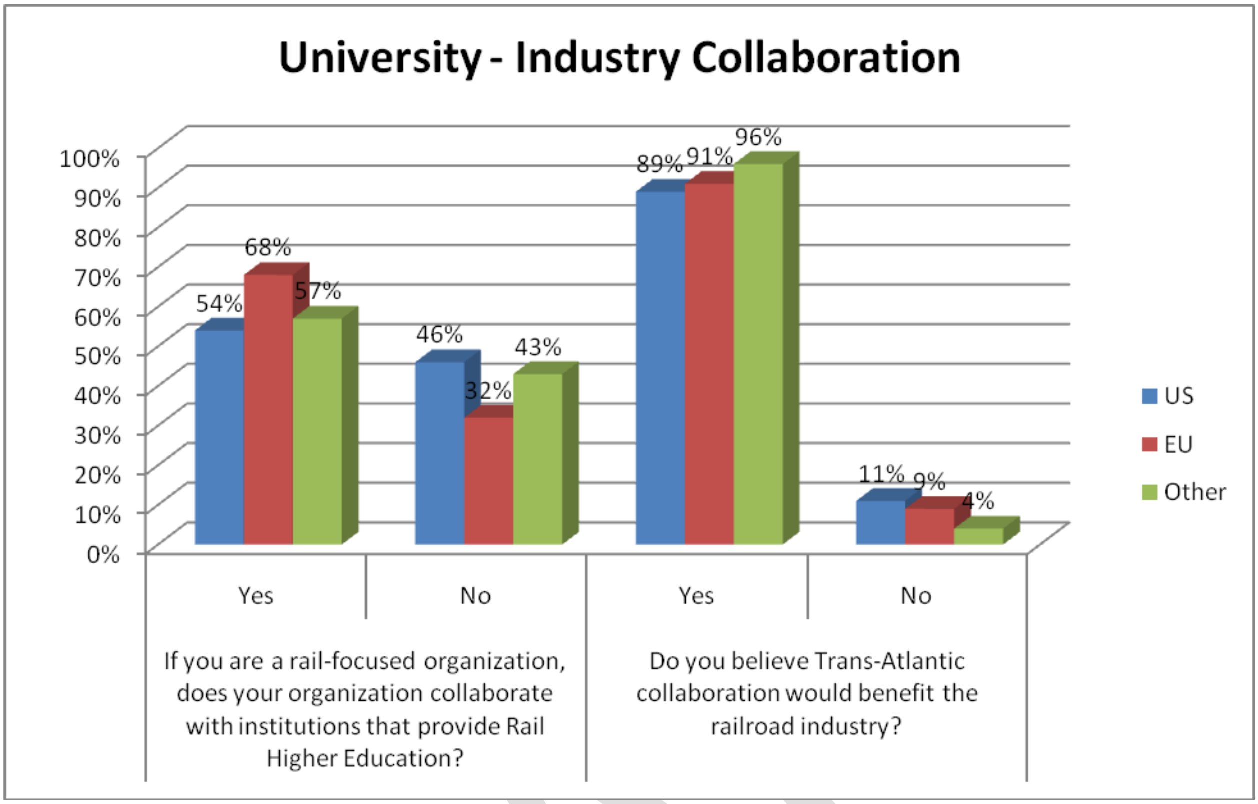

Figure 4.11 - Industry Collaboration with Universities

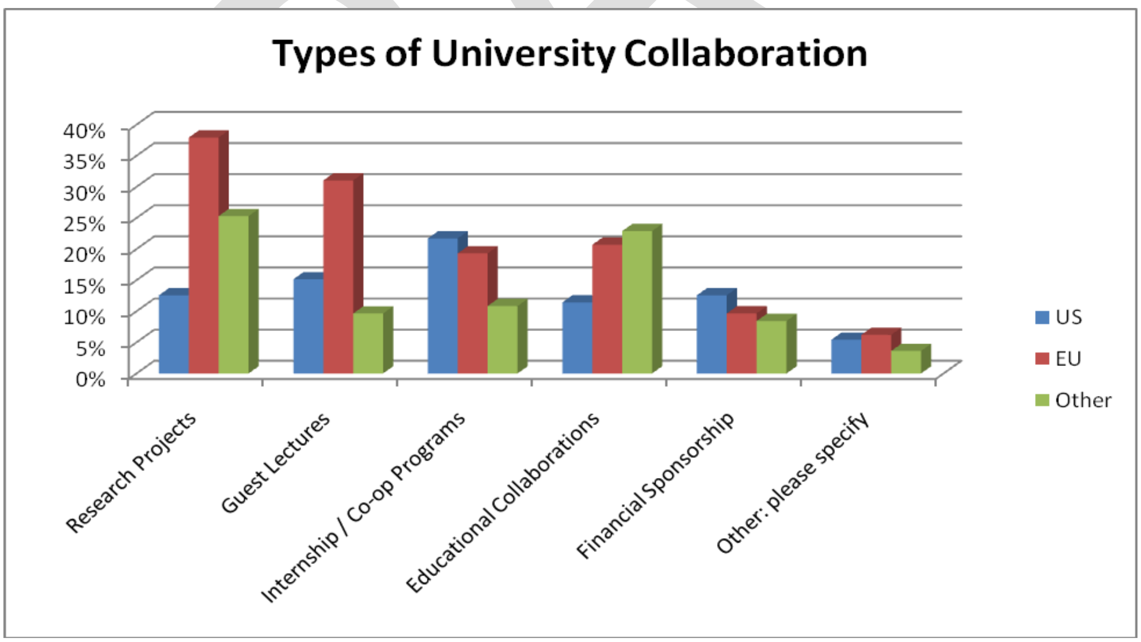

Figure 4.12 - Types of Industry/University Collaboration

4.1.2 Survey Part II – Recruitment / Development Managers

Part II of the survey was targeted for industry professionals who were more involved in workforce development and recruitment effort and questions focused on core competences, preferred background, and university relations. Part II was completed by about 150 respondents and they displayed a similar geographic and gender division as Part I respondents.

One of the topics in Part II was the demand for employees in the rail industry. The majority of respondents have seen an increase in the number of employees within their company or department over the past five years and this was especially noted by U.S. respondents (Figure 4.13). The majority of respondents also expected that the number of positions in their organizations would increase over the next three years, and there would be an increased demand for students with a background in rail studies (Figure 4.13). The U.S. respondents had the most optimistic outlook on future recruitment.

Figure 4.14 and 4.15 summarize the results of questions that were asked to determine levels of cooperation between universities and the rail industry. Almost 50% of E.U. universities have soft partnership or relationship with the rail industry but only 25% of U.S. universities have an established partnership. Figure 4.15 identifies that the main reason for not having a relationship is a perceived time commitment rather than a lack of desire for a partnership.

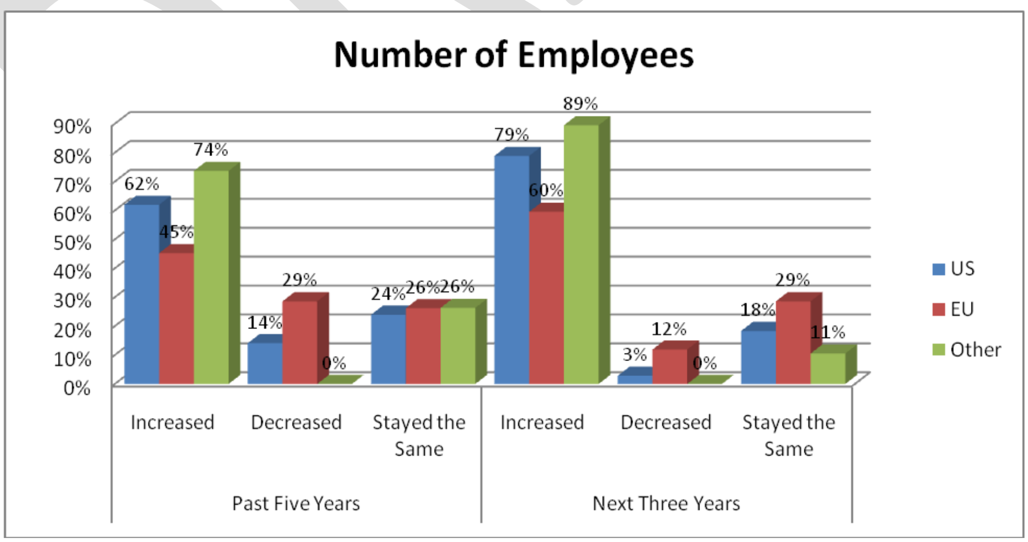

Figure 4.13 - Number of Employees – Past Five and Next Three Years

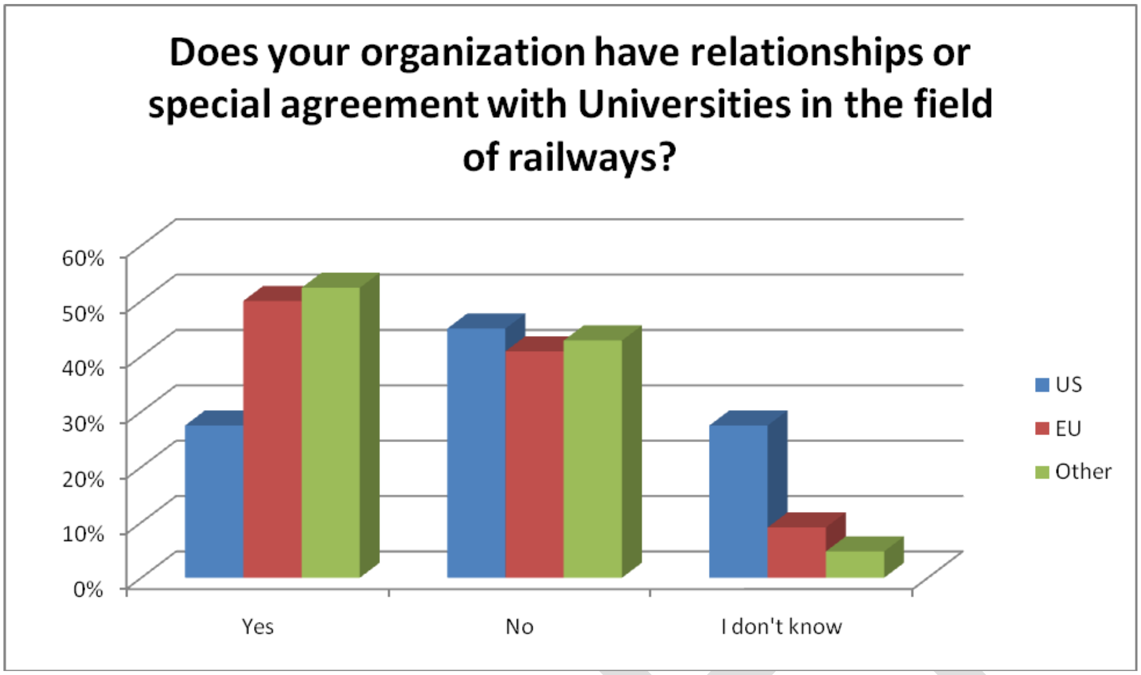

Figure 4.14 - Industry–University Agreement Frequency

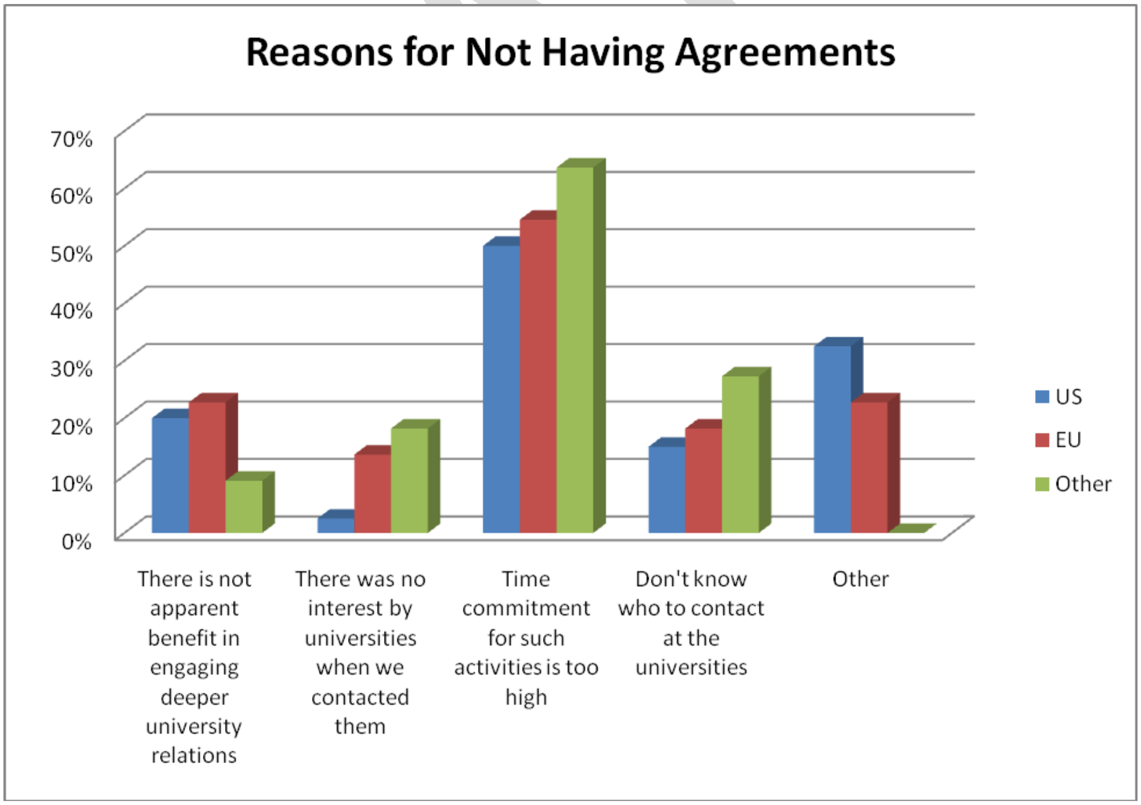

Figure 4.15 - Reasons for Lack of Railway – University Agreements

4.1.3 University Education

The following tables (Tables 4.2-4.3) explore the results from questions related to the most desired types or experiences of university education. The results of Table 4.3 show a high degree of correlation between the U.S. and E.U.. These similarities can also be seen in the highest ranked rail courses shown in Table 4.2. It should be noted that while some of the rankings are low for certain topics, such as online/distance education and rail entrepreneurial programs, many of these types of rail courses are relatively new and thus have fairly limited visibility and industry exposure.

Table 4.4 and Table 4.5 highlight the benefits of university participation in the railway field. The greatest areas of interest relate to providing basic railway education and undertaking railway research. The high rankings across the board suggest a desire by the rail industry to increase collaboration between the industry and universities and much of this can be achieved through improved communications and working to understand the other partner.

Table 4.2 - Highest ranked beneficial rail courses

	United States	European Union	Other
1st	Co-ops and/or Internships (4.17)	Introduction to Rail (5-10 lecture hours) (3.44)	Semester Long Course in Railroad Engineering (3 Credits) (4.29)
2nd	Semester Long Course in Railroad Engineering (3 Credits) (4.07)	Opportunities for Funded Student Research in Rail Topics (3.39)	Graduate Studies in Railroad Engineering (45 Credits) (4.25)
3rd	Graduate Studies in Railroad Engineering (45 Credits) (3.73)	Co-ops and/or Internships (3.36)	Co-ops and/or Internships (4.06)
4th	Introduction to Rail (5-10 lecture hours) (3.70)	Semester Long Course in Railroad Engineering (3 Credits) (3.32)	Seminar or Certificate in Rail Topics (3.76)
5th	Minor in Railroad Engineering (12 Credits) (3.69)	Graduate Studies in Railroad Engineering (45 Credits) (3.30)	Introduction to Rail (5-10 lecture hours) (3.71)* Minor in Railroad Engineering (12 Credits) (3.71)*

** Indicates a tie in score between two categories.*

Table 4.3 - Beneficial Rail Courses

What types of university education would you consider most beneficial for graduates? (1 – Not Important, 2 – Somewhat Important, 3 – Important, 4 – Very Important, 5 – Extremely Important)	United States	European Union	Other	Overall Average
Introduction to Rail (5-10 lecture hours)	**3.70**	**3.44**	**3.71**	**3.61**
Seminar or Certificate in Rail Topics	**3.46**	**3.02**	**3.76**	**3.42**
Semester Long Course in Railroad Engineering (3 Credits)	**4.07**	**3.32**	**4.29**	**3.89**
On-Line or Distance Education Course	**3.16**	**2.78**	**3.24**	**3.06**
Minor in Railroad Engineering (12 Credits)	**3.69**	**3.00**	**3.71**	**3.47**
Rail Entrepreneurial Programs (Student Companies)	**2.68**	**2.71**	**3.24**	**2.88**
Opportunities for Funded Student Research in Rail Topics	**3.47**	**3.39**	**3.65**	**3.50**
Graduate Studies in Railroad Engineering (45 Credits)	**3.73**	**3.30**	**4.25**	**3.76**
Co-ops and/or Internships	**4.17**	**3.36**	**4.06**	**3.86**
Other	**1.31**	**1.27**	**2.50**	**1.70**

Table 4.4 - Highest Beneficial Areas for Increased University Participation

	United States	European Union	Other
1st	Providing Basic Railway Education (Introductory Lectures, Seminars or a Single Course) (3.84)	Undertaking Railway Research (3.73)	Promoting Rail Transportation (4.18)
2nd	Promoting Rail Transportation (3.65)*	Providing Basic Railway Education (Introductory Lectures, Seminars or a Single Course) (3.61)	Promoting rail Industry and Culture (4.12)*
3rd	Undertaking Railway Research (3.65)*	Maximizing Rail's Energy Efficiency (3.45)	Providing Basic Railway Education (Introductory Lectures, Seminars or a Single Course) (4.12)*
4th	Providing Specialized Education (3.61)	Promoting rail Industry and Culture (3.41)	Maximizing the Benefits of the Railway to the Environment (4.06)
5th	Promoting Rail Industry and Culture (3.59)	Maximizing the Benefits of the Railway to the Environment (3.39)	Undertaking Railway Research (3.94)

** Indicates a tie in score between two categories.*

Table 4.5 - Beneficial Areas for Increased University Participation

Would increased university participation be beneficial in following topics? (1 – Not Important, 2 – Somewhat Important, 3 – Important, 4 – Very Important, 5 – Extremely Important)	**United States**	**European Union**	**Other**	**Overall Average**
Recruitment	**3.43**	**2.71**	**3.53**	**3.22**
Providing Specialized Education	**3.61**	**3.12**	**3.71**	**3.48**
Promoting Rail Transportation	**3.65**	**3.15**	**4.18**	**3.66**
Increasing Customer Satisfaction	**2.93**	**2.55**	**3.41**	**2.97**
Boosting Rail Productivity and Competitiveness	**3.22**	**3.07**	**3.59**	**3.30**
Maximizing Rail Safety and Security	**3.32**	**3.18**	**3.88**	**3.46**
Maximizing Railway System's Capacity	**3.36**	**3.07**	**3.63**	**3.35**
Encouraging Modal Shift and Intermodal Services	**3.08**	**3.02**	**3.41**	**3.17**
Promoting rail Industry and Culture	**3.59**	**3.41**	**4.12**	**3.70**
Providing Basic Railway Education (Introductory Lectures, Seminars or a Single Course)	**3.84**	**3.61**	**4.12**	**3.86**
Undertaking Railway Research	**3.65**	**3.73**	**3.94**	**3.78**
Maximizing the Benefits of the Railway to the Environment	**3.49**	**3.39**	**4.06**	**3.65**
Maximizing Rail's Energy Efficiency	**3.56**	**3.45**	**3.80**	**3.60**

4.2 *Comparative assessment of the Competence Gap between the European Union and United States in the railway industry*

One of the objectives of TUNRail was to evaluate how well today's education meets the industry demands and needs. The methodology used for the assessment was a competence gap analysis where outcomes of university course surveys were compared with outcomes from the industry survey. The following section provides background to the methodology and analysis of the data.

4.2.1 Background

In the course of the last century, the role of universities has shifted from a simple repository of knowledge somewhat detached from real world towards a central positioning in countries' success and societies' development (Winterton et al, 2005, Enders and Fulton, 2002, Zaky and El-Faham, 1998)[26]. With more or less enthusiasm universities have been embracing this new role. Universities, notably in the U.S., have already established strong interactions with industry and society partially due to the free-market-economy based industry and the non-centralised higher education system (Zaky and El-Faham, 1998). United States universities have competed for students and funding throughout the history, while E.U.'s public and centralised higher education system has only recently considered the opening of educational markets to competition. As such, E.U. universities are behind their U.S. counterparts in this approach, but they are catching up as they recognise the benefits of such interactions. Indeed, important benefits and synergies may accrue for both universities and industries from their interactions, such as:

- Benefits to universities:

[26] Enders, J., Fulton, O., Higher education in a globalising world: international trends and mutual observations, Kluwer Academics Publsihers, Amsterdam, 2002.

Zaky, A., El-Faham, M., "The University-Industry Gap and its Effect on Research and Development in Developing Countries", *Engineering Science and Education Journal*, Vol 7, pp 122-125, 1998.

Winterton, J., Delamare-Le Deist, F., Stringfellow, E., "Typology of knowledge, skills and competences: clarification of the concept and prototype", Centre for European Research on Employment and Human Resources - Groupe ESC Toulouse, 2005.

- *Placement and sourcing of students* - deeper university-industry interactions create good opportunities for student internships that could easily result in permanent jobs after graduation. The rail industry can also be a valuable source of students for graduate or other courses and thus feed universities’ classrooms. On the other hand, graduates with rail exposure during their studies are better prepared to contribute to the company immediately upon hiring and possess higher potential to remain with the employer.
    - *Insight into industry needs* - universities get a better understanding on the actual requirements and demands placed by the industry that could encourage improvements to the curricula and identify new research opportunities.
    - *Research and continuing education opportunities for faculty* - industry's problems and challenges are an endless source of new research opportunities and collaboration projects tend to be more beneficial and valuable for both parties.
    - *Additional source of funding* - industry is more willing to fund university research if collaboration and interaction is strong.
- Benefits to industry:
    - *Customised education and training* - universities can provide customised courses (or workshops) at special fees.
    - *Influence on academic programs* - industry may comment and advise on the curricula and course content so that it better meets their needs.
    - *Access to new knowledge* - a strong interaction with universities may open the door to industries to access new technologies, models, techniques, materials, or processes, etc. before other competitors
    - *New revenue sources* – industries may develop new products and markets based on academic research outputs. In addition, universities may leverage industry to

access certain types of funding. (Zaky and El-Faham, 1998, Beckman et al, 1997)[27]

Notwithstanding their efforts, universities have found it challenging to align their curricula with industry's needs and graduate students with the relevant competences, skills and knowledge. Several reasons can be identified that contribute to the difficulties (Zaky and El-Faham, 1998):

- University-industry interaction is not included in university's promotion and rewarding schemes;
- Heavy teaching loads do not leave time for engagement in university-industry interactions;
- University career development does not require interaction with industry and many faculty staff have never held a position outside of the university environment;
- University research is valued in terms of publication record and not on their practical nature for industry application;
- University research timing is not suitable for the industry's rhythm. University develops research on long term cycles and expectations, whereas industry's goals are short term oriented.
- Economies are highly volatile and dynamical, and industries are always exploring and introducing new services and products. This economic paradigm requires permanently new knowledge, skills and, ultimately, competences; and both new and experienced employees are expected to keep up to date with such evolutions and requirements.

As a consequence of these difficulties, a competence gap between what is demanded by industry and what universities can offer is visible (Zaky and El-Faham, 1998, Beckman et al, 1997). The competence gap is challenging at several levels. Firstly, the inadequacy of the students' skills and

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[27] Beckman, K., Coulter, N., Khajenoori, S., Mead, N., "Collaborations: Closing the Industry–Academia Gap", *Software Journal*, IEEE, Vol 14, Issue 6, pp 49-57, 1997.

Zaky, A., El-Faham, M., "The University-Industry Gap and its Effect on Research and Development in Developing Countries", *Engineering Science and Education Journal*, Vol 7, pp 122-125, 1998.

competences requires employers invest in in-house training or search for professionals elsewhere. The need for training delays the time of market entrance of the students and increases the costs for the employers. Secondly, the universities won't meet their main objective of educating and preparing students for the job market. Thirdly, the students, arguably the main victims of the gap, start from a disadvantaged competitive position vis-à-vis other workers and may have to endure further, in many cases, self-funded education. Finally, if government funding channelled to universities does not generate the expected benefits, industries may lose their competitive edge and jeopardise the countries' future development.

4.2.2 Basic Definitions

A competence gap analysis requires an understanding of the following key concepts:

- Knowledge,
- Skill,
- Competence,

4.2.2.1 Knowledge

Knowledge can be defined as the "inferred capability which makes possible the successful performance of a *class of tasks* that could not be performed before [a] learning [process] was undertaken" (Gagné, 1962, pp 355)[28]. In turn, a learning process can be understood as capacity of an individual, in face of a set of stimulus, to acquire the capability to solve a given class of tasks. As such, knowledge is the outcome of the interaction between an individual's capacity to learn (intelligence) and the opportunity for the action (Winterton et al, 2005)[29].

Knowledge can be segmented according to its purpose and nature. General knowledge refers to knowledge that is necessary for a person's daily activity and interaction with others in society. This type of knowledge is irrespective of any occupational context. Conversely, specific knowledge refers to knowledge gained in a specific context to meet specific requirements or conduct specific tasks. In addition, knowledge is cumulative and built over time based on

[28] Gagné, R. M. (1962) 'The acquisition of knowledge, Psychological Review, Vol 69, pp 355-365

[29] Winterton, J., Delamare-Le Deist, F., Stringfellow, E. (2005) Typology of knowledge, skills and competences: clarification of the concept and prototype, Centre for European Research on Employment and Human Resources - Groupe ESC Toulouse

previous acquired knowledge, as individual gains an explicit and factual knowledge on a given task (declarative knowledge), which will support the capability of utilising the knowledge in new tasks and different contexts (procedural knowledge) (Winterton et al, 2005)[28].

4.2.2.2 Skill

Skill can be defined as "goal-directed, well-organised behaviour that is acquired through practice and performed with economy of effort" (Proctor and Dutta, 1995, 18)[30]. In other words, skill refers to how well an individual is able to execute a given task. Typically, skill is a goal-oriented behaviour denoting that it is manifested in response of an external demand. It is also a well-organised behaviour that exhibits structure and a coherent set of patterns. Skill is acquired and improved over time through repetition and the efforts and cognitive demands reduce as the skill improves (Winterton et al, 2005).

Different types of skills have been identified, depending on the nature of the external demand, namely:

- *Perceptual skill* is related with an individual's ability to make distinctions and judgements;
- *Response skill* is related with an individual's ability to promptly react to a specific demand. This type of skill can be improved and, eventually, becomes automatic, if practiced over time.
- *Motor skill* is related with an individual's ability to perform some motor-related behaviour, such as speed and accuracy of physical movements, or dexterity. Indeed, this type of skill was one of the firsts to be identified (Swift, 1904, 1910, Bryan and Harter, 1897 and 1899)[31].

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[30] Proctor, W., Dutta, A. "Skill Acquisition and Human Performance", *Sage Publication*, London, 1995.

[31] Bryan, W., Harter, N. "Studies in the physiology and psychology of the telegraphic language", *Psychological Review*, Vol 4, pp 27-53, 1897.

Bryan, W., Harter, N. "Studies on the telegraphic language: The acquisition of a hierarchy of habits", Quarterly *Journal of Experimental Psychology*, Vol 10, pp 113-129, 1899.

Swift, E. J. "The acquisition of skill in typewriting: A contribution to the psychology of learning", *Psychological Bulletin*, Vol 1, pp 295-305, 1904.

Swift, E." Learning to telegraph", *Psychological Bulletin*, Vol 7, pp 149-153, 1910.

- *Problem-solving skill* is related with an individual's ability to solve new (or unknown) tasks. This skill is dependent upon intellectual and mental models.

4.2.2.3 Competence

There are several definitions in the literature on the concept of competence and, the related term, competency.[32] The reasons are discussed elsewhere in detail,[33] but they may be ascribed to different epistemological assumptions, cultural differences or, even, differences in the context of the study (or nature of object of analysis). Mansfield has identified three different contexts where the notion can be applied[34], being:

- A characteristic that describes how an individual performs (and fulfils) their job's demands. The better one meets (and fulfils) their job's demands, the higher their competence will be. This notion is focussed on the outcome of an individual's job's activity.
- Individual's attributes and traits to meet the job's demands. This notion is focussed on the individual's intrinsic properties.

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[32] Winterton, J., Delamare-Le Deist, F., Stringfellow, E., *Typology of knowledge, skills and competences: clarification of the concept and prototype*, Centre for European Research on Employment and Human Resources - Groupe ESC Toulouse, 2005.
Hoffmann, T., "The meanings of competence", *Journal of European Industrial Training*, Vol 23, Issue 6, pp 275-285, 1999.

Elleström, P-E. 'The many meanings of occupational competence and qualification", *Journal of European Industrial Training*, Vol 21, Issue 6/7, pp 266-273, 1997.

Robotham, D., Jubb, R., "Competences: measuring the unmeasurable, Management Development Review", Vol 9, Issue 5, pp 25-29, 1996.

[33] Jeris, L., Johnson, K. 'Speaking of Competence: Toward a Cross-translation for Human Resource Development (HRD) and Continuing Professional Education (CPE)," Academy of Human Resource Development Annual Conference, Austin, TX, 4-7 March, Proceedings Vol.2, 1103-1110, 2004.

Cseh, M., "Facilitating learning in multicultural teams", *Advances in Developing Human Resources*, Vol 5, Issue 1, pp 26-40, 2003.

Pate, J., Martin, G. and Robertson, M., "Accrediting competencies: a case of Scottish vocational qualifications", *Journal of European Industrial Training*, Vol 27, Issues 2/3/4, pp 169-176, 2003.

Boon, J., van der Klink, "M. Competencies: The triumph of a fuzzy concept", *Academy of Human Resource Development Annual Conference*, Honolulu, HA, 27 February- 3 March, Proceedings Vol.1, pp 327-334, 2002.

[34] Mansfield, B., "Competence in transition", *Journal of European Industrial Training*, 28(2/3/4): 296-309, 2004.

- Task that an individual does, such as job task. The tasks are defined by the type of demands of the job.

For the purpose of this study, Woodruffe's definition was adopted on competence and competency[35]. The author defines *competence as a (job's) task that an individual can perform*, and *competency as an individual's capability (or characteristic) of doing well a given (job's) task*. This definition is supported by other authors, such as Le Deist and Winterton,[36] Hartle,[37] or Tate[38]. The definition of competence has a functional nature related to the properties (and functions) of a task or job; while competency has a behavioural nature related to what individual can achieve.

An individual's competence is built over time, and several factors influence its development, namely: ability, knowledge, understanding, skill, action, experience or motivation (Weinert, 2001)[39]. Among these, skill is a fundamental prerequisite.

4.2.2.4 Interaction between Knowledge, Skill and Competence

Although knowledge, skill and competence refer to different psychological components of human development, they influence each other and their development is determined by the others. It should be noted that as with any psychological component, many other factors

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[35] Woodruffe, C., "Competent by any other name", *Personnel Management*, September 1991, pp 30-33

[36] Winterton, J., Delamare-Le Deist, F., Stringfellow, E., *Typology of knowledge, skills and competences: clarification of the concept and prototype*, Centre for European Research on Employment and Human Resources - Groupe ESC Toulouse, 2005.

[37] Hartle, F., How to Re-engineer your Performance Management Process, London: Kogan Page, 1995.

38 It should be noted that other authors consider precisely the opposite, or with other meanings. For example, Mangham (1986) related competence with a personal models; McClelland (1976) related competency with superior performance; or Dale and Iles (1992) use both terms interchangeably.

Mangham, I. 'In search of competence', *Journal of General Management*, Vol 12, Issue 2, pp 5-12, 1986.

McClelland, D. *A Guide to Job Competency Assessment*, Boston: McBer & Co, 1976.

Dale, M. and Iles, P., *Assessing Management Skills*, Kogan Page, London, 1992.

Tate, W., Developing Corporate Competence: A High-Performance Agenda for Managing Organisations, London: Gower, 1995.

[39] Weinert, F. (2001) Vergleichende Leistungsmessung in Schulen eine umstrittene Selbstverständlichkeit. In F. E. Weinert (Ed.) Leistungsmessungen in Schulen, Weinheim und Basel: Beltz Verlag, pp 17-31

influence their development. For the purposes of this research, it is relevant to highlight the cascade of influence between key components (Figure 4.16). An individual's intellectual capabilities are required for the development of knowledge and the practical utilization and “operationalization” of knowledge is condition for developing skills. All these components are necessary prerequisites for the development of competences.

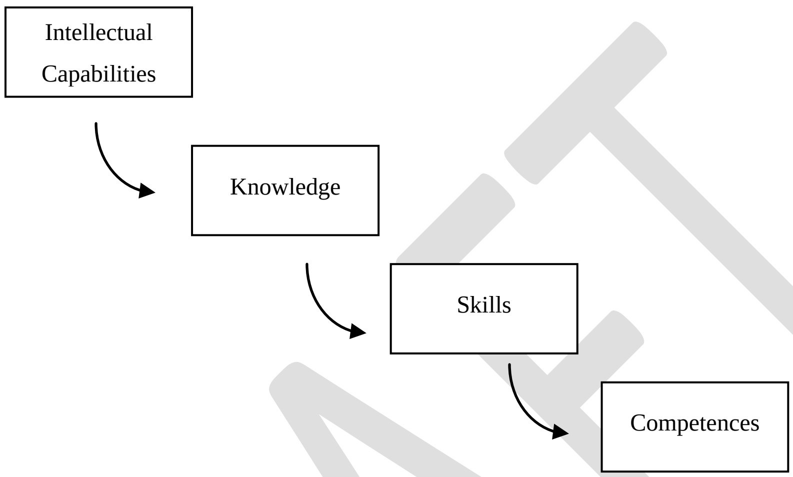

Figure 4.16 - Influence between knowledge, skills and competences

4.3 Competence Gap Analysis Framework

Figure 4.17 represents the competence gap and the basis of analysis in the TUNRail project in a simplified manner. On the left side, we have the industry (and society) that generates and defines the demand of competences in the railway related jobs. On the right side, we have the educational (and research) institutes that supply the students with a given set of competencies. If the students’ competencies do not match industry’s required competences, the result is a competence gap. The research team has attempted to identify competence gaps between current rail higher education and industry expectations and to determine if the nature of the gap in the E.U. is different than the U.S.

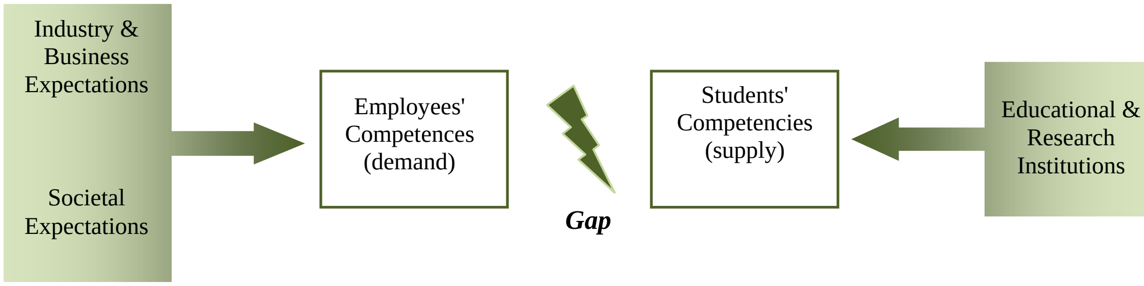

Figure 4.17 - Potential competence gap

The research team believes that the simplified representation of the competence gap through the scheme in Figure 4.17 is inadequate, because it is represents an aggregated level and it masks other gaps. To take the analysis a step further, the gap between university and industry can be decoupled into four gaps between the four fundamental agents - University, Industry, Students, and Employees. As such, a total of four gaps are identified between the four fundamental agents involved in the industry-education relationship and are presented in Figure 4.18.

The university is the repository of knowledge and it plays the role of developing a set of competencies for an individual student. The student is a person that through a university program builds knowledge on a given domain and develops a certain set of skills and competencies. The company is the economic agent that produces a set of products and services which require a set of competences to be met by the employees. The employees are the agents that work for the company and they have a set of skills that will define their level of competence. Some employees are former students.

Using the four-gap assessment framework it helps in the identification of the four gaps and a better understand of the positioning and origin of the Competence Gap (Gap) (Figure 4.19).

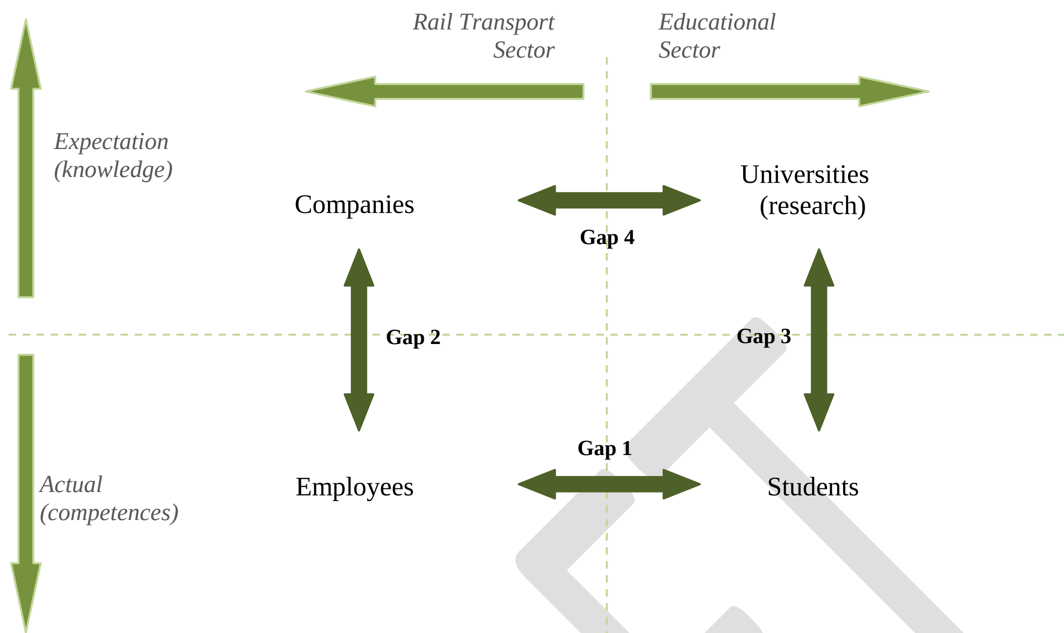

Figure 4.18 - The four gaps framework

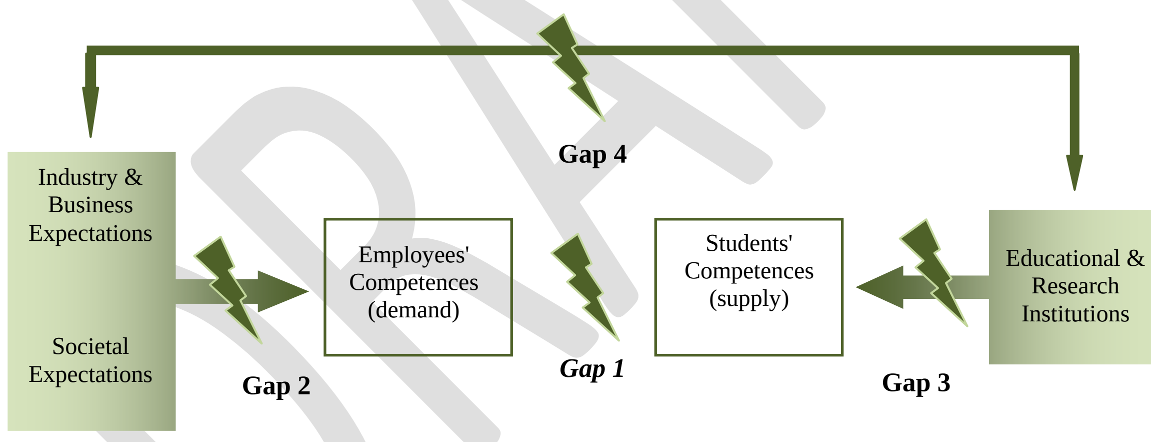

Figure 4.19 - Competence Gaps

A potential gap exists between each of the pairs, as follows:

- Gap 1 - Competence Gap – The Gap between the competencies that the employees need and the actual competencies of the students (i.e. to what extent are the students' competencies actually useful in their working daily activities?)
- Gap 2 – The Gap between the knowledge that the companies expect to receive and the actual proficiency the employers perceive on the employee (i.e. to what extent do the employees' competencies actually fit in the companies' requirements?)

- Gap 3 – The Gap between the knowledge that the universities generate and the actual competencies of the students (i.e. is the knowledge generated in the research transferred in the courses?)
- Gap 4 – The Gap between the knowledge the companies need and the knowledge the universities have (i.e. is the universities' research and teaching activities of relevance for the companies?)

TUNRail has explored the teaching of railways and the state of the industry in the European Union and the United States. As such, the team focused the analysis on the 'horizontal competence gaps' between the Educational Sector and the Rail Transport Sector, Gap 1 and to certain degree Gap 4.

4.4 Assessment of the Gap

4.4.1 Methodology

The team deployed a four-step methodology to assess the Competence Gap (Figure 3.20). The primary tools for collecting the data were the university course survey and the industry survey. However, it should be noted that both the industry survey (Step 2) and the course survey (Step 3) were used to collect data for other purposes, so they contained more information than was required to assess the competence gaps.

4.4.1.1 Step 1 - Identification of the competences

As discussed above, a competence is an individual’s characteristics (or capability) useful for accomplishing job’s tasks. The literature on required competences from railway professionals was scarce. Only one reference was found relevant in European Union. The E.U. funded project E.U.RNEX[40] - European Rail Research Network of Excellence conducted a survey to the European railway operators aiming to understand their current needs of competences[41]. The project identified a total of thirty-five competences, clustered around eight core competence areas.

[40] IST team member was a member in this Project.
[41] "Report on offered educational courses and railway operators needs - D16", E.U.RNEX - European Rail research Network of Excellence, 2004

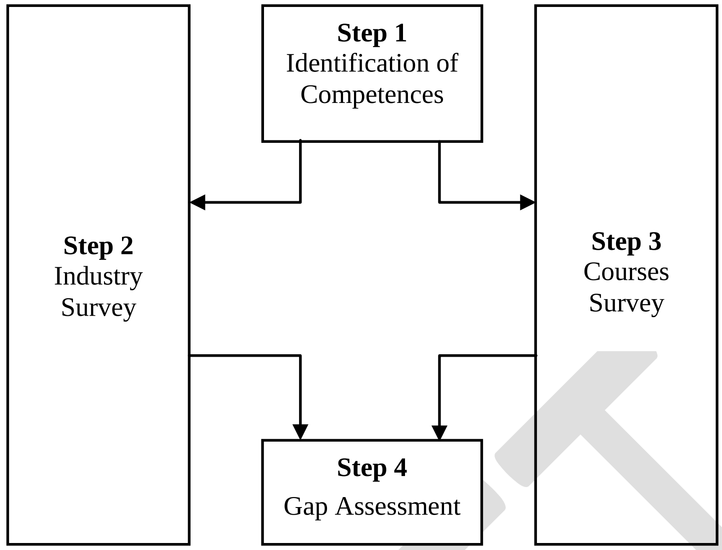

Figure 4.20 - Gap Assessment Methodology

These competences formed a foundation for the industry survey that used a similar structure. The eight core competence areas were:

- Rolling stock and traction;
- Systems Engineering;
- Civil Engineering;
- Control System;
- Operations;
- Economics, Business and Regulation;
- Environment;
- Multidisciplinary Issues.

4.4.1.2 Step 2 - Industry Survey (demand of competence)

The objective of this step was to identify the most valued competences for working in the rail industry. The key outcomes of the survey are summarized in this section.

Each respondent was requested to rank from one to five the importance of individual competences under each core competence group. A Five ranking was judged as extremely important and one was judged as not important. The rankings between core competence groups are presented in Figure 4.21 and each individual competence rankings in Tables 4.6 and 4.7. The results demonstrated significant differences between the E.U. and the U.S. In the European Union, the core competences most valuated are in the *environment*, *systems engineering,* and *economy, business and regulations*; whereas in the United States, they are the *civil engineering and infrastructures*, *environment* and *economy, business and regulations.* The difference between the European Union and the United States can have several explanations. Firstly, they are the natural consequence of the results obtained for the domains of knowledge. In the U.S., *civil engineering* was the domain most valuated, therefore, it is natural the competences in *civil engineering and infrastructure* are likewise highly evaluated. In the E.U., environmental protection and sustainable development are key political issues and major drivers of development, thus it is natural the major demand for this type of competences. Most interesting is the fact that the competence *civil engineering and infrastructure* was the least valuated in the European Union, which may result from the fact that the railway's infrastructure is rather mature and other concerns are nowadays more relevant. Another potential explanation is the large portion of civil engineers responding to the survey in U.S. while in Europe, more respondents came for areas outside engineering.

From engineering perspective the outcomes show that E.U. places a higher emphasis on engineering competencies relating to rolling stock and systems engineering, while the U.S. respondents placed a high emphasis on the infrastructure side - track design and structures. These outcomes may be partially due to the U.S. pool of respondents which were more civil engineering oriented. Both the E.U. and U.S. placed a similar emphasis on control systems, although the E.U. values more skills in electromagnetic topics, probably due to a higher prevalence of electrified railways.

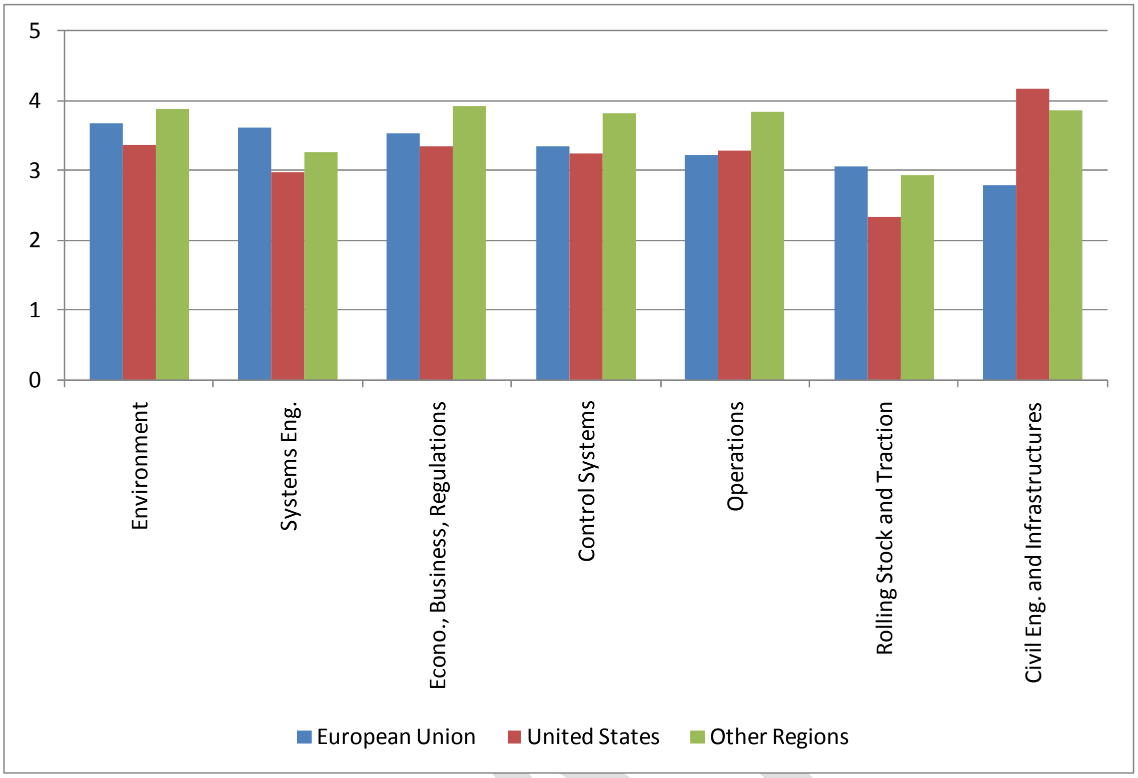

Figure 4.21 - Competences

Table 4.6 - Highest Ranked Engineering Competencies

	United States	European Union	Other
1st	Tracks, Switches, and Crossings (4.34)	System Integration and Engineering (3.67)	Tracks, Switches, and Crossings (4.19)
2nd	Structures (4.31)	Interoperability (3.65)	Signaling, Control Command and Interlocking (4.14)*
3rd	Stations (3.81)	Testing Verification and Qualifications (3.56)	Train Control, Positioning and Communications (4.14)*
4th	Signaling, Control Command and Interlocking (3.62)	Traction and Power Supply (3.51)	Structures (4.00)
5th	Train Control, Positioning and Communications (3.50)	Train Control, Positioning and Communications (3.47)	Traction and Power Supply (3.57)

** Indicates a tie in score between two categories.*

Table 4.7 - Complete Engineering Competency Rankings

What types of university education would you consider most beneficial for graduates? (1 – Not Important, 2 – Somewhat Important, 3 – Important, 4 – Very Important, 5 – Extremely Important)	United States	European Union	Other	Overall Average
Rolling Stock and Traction				
Car Body and Construction	**2.27**	**2.68**	**2.95**	**2.63**
Bogies, Running Gear and Braking	**2.41**	**3.20**	**3.14**	**2.92**
Interiors, Auxiliaries, HVAC	**2.04**	**2.89**	**2.43**	**2.45**
Traction and Power Supply	**2.63**	**3.51**	**3.57**	**3.24**
Other	**1.38**	**2.51**	**2.08**	**1.99**
Systems Engineering				
Interoperability	**2.84**	**3.65**	**3.00**	**3.16**
System Integration and Engineering	**3.08**	**3.67**	**3.19**	**3.31**
Testing Verification and Qualifications	**3.04**	**3.56**	**3.35**	**3.32**
Other	-	-	-	-
Civil Engineering and Infrastructure				
Tracks, Switches, and Crossings	**4.34**	**2.88**	**4.19**	**3.80**
Structures (Bridges, Tunnels, (etc.)	**4.31**	**2.55**	**4.00**	**3.62**
Stations	**3.81**	**2.93**	**3.35**	**3.36**
Other	**2.53**	-	**1.33**	**1.93**
Control Systems				
Signaling, Control Command and Interlocking	**3.62**	**3.23**	**4.14**	**3.67**
Train Control, Positioning and Communications	**3.50**	**3.47**	**4.14**	**3.70**
Electromagnetic Compatibility	**2.61**	**3.33**	**3.00**	**2.98**
Other	-	-	-	-

Table 4.8 and Table 4.9 summarizes findings related to the importance of operations and management competencies. In general, each attribute is ranked highly. There is higher emphasis on freight rail in the U.S. and passenger rail in the E.U.. Other noticeable differences displayed in the table include a higher emphasis on environmental issues, economics / regulations, and safety issues in the E.U..

Table 4.8 - Highest Ranked Operations and Management Competencies

	United States	European Union	Other
1st	Regulations (3.76)	Reliability, Availability, Maintenance and Safety (RAMS) (4.05)	Human Factors (4.29)
2nd	Quality Management (3.71)	Security and Safety (4.00)	Risk Analysis and Failure Mode Analysis (4.25)
3rd	Freight (3.70)	Regulations (3.93)	Regulations (4.20)
4th	Cost, Asset Management, Life Cycle Costs (3.59)	Risk Analysis and Failure Mode Analysis (3.88)	Security and Safety (4.15)
5th	Air Pollution and Energy Savings (3.49)* Reliability, Availability, Maintenance and Safety (RAMS) (3.49)*	Cost, Asset Management, Life Cycle Costs (3.86)* Air Pollution and Energy Savings (3.86)* Quality Management (3.86)*	Quality Management (4.14)

** Indicates a tie in score between categories.*

Table 4.9 - Complete Operations and Management Competency Rankings

What types of university education would you consider most beneficial for graduates? (1 – Not Important, 2 – Somewhat Important, 3 – Important, 4 – Very Important, 5 – Extremely Important)	United States	European Union	Other	Overall Average
Operations				
Passenger	**3.48**	**3.77**	**3.60**	**3.62**
Freight	**3.70**	**2.79**	**3.85**	**3.45**

Technical and Commercial Exploitation	**2.93**	**3.37**	**3.71**	**3.34**
Resources Management	**3.01**	**3.44**	**4.14**	**3.53**
Intermodality	**3.26**	**2.79**	**3.90**	**3.32**
Other	-	-	-	-
Environment				
Noise and Vibrations	**3.38**	**3.58**	**3.81**	**3.59**
Air Pollution and Energy Savings	**3.49**	**3.86**	**4.00**	**3.78**
Sustainable Development, Recycling and Waste Management	**3.20**	**3.60**	**3.84**	**3.55**
Other	-	-	-	-
Economics, Business, Regulations				
Economics	**3.33**	**3.58**	**3.84**	**3.59**
Regulations	**3.76**	**3.93**	**4.20**	**3.96**
Business Management	**3.29**	**3.60**	**3.85**	**3.58**
Cost, Asset Management, Life Cycle Costs	**3.59**	**3.86**	**4.00**	**3.81**
Marketing Management	**2.93**	**3.14**	**3.67**	**3.25**
Public Service, Social and Political Issues	**3.12**	**3.05**	**3.95**	**3.37**
Other	-	-	-	-
Multidisciplinary Issues				
Security and Safety	**3.63**	**4.00**	**4.15**	**3.93**
Risk analysis and Failure Mode Analysis	**3.30**	**3.88**	**4.25**	**3.81**
Human Factors	**3.29**	**3.51**	**4.29**	**3.70**
Reliability, Availability, Maintenance and Safety (RAMS)	**3.49**	**4.05**	**3.95**	**3.83**
Quality Management	**3.71**	**3.86**	**4.14**	**3.90**
Computer Technology and Networking	**3.51**	**3.67**	**4.10**	**3.76**
Light Rail, Tram and Tram-train Systems	**3.34**	**2.74**	**3.65**	**3.23**
Other	-	-	-	-

Since an individual's knowledge and skills influence the nature of their competences, the research team investigated the background knowledge and skills on which those competences were built. Two students may acquire a same competence although they took distinct programs, but their knowledge and skills will be different which naturally will reflect in characteristics of the competence (Figure 4.22). For example:

- The competence in maintenance of railways infrastructure is certainly different for a civil engineering student than for a transportation engineering student. Both students could learn the same contents and acquire the same competences. However, one student spends the duration of the program acquiring knowledge in other areas of civil engineering that could be useful in maintaining the infrastructure of railways (for example, material construction, design and architecture of structures, or geotechnics), although these topic may not be related to that competence.
- The competence in procurement is again certainly different for an economics student than for a transportation engineering student, for similar reasons as described above. The economics student acquires knowledge in areas that will be useful, but they do not directly contribute to that competence.

The team utilized information on the most desired educational background (or programs) and on preferred individual skills and characteristics for the analysis.

Table 4.10 presents the top five rankings by educational background. For U.S. respondents, civil engineering is the top ranked educational background followed by railways and electrical engineering, while in the E.U., railways is the top educational background requirement followed by mechanical and electrical engineering. This positioning is probably the results of the efforts undertaken to improve the interoperability of the continent's railways. A complete list of all backgrounds and rankings is presented in Table 4.11. One particularly divergent area is displayed within the engineering disciplines, where the most desired discipline in the U.S. is civil engineering, while the most desired discipline in the E.U. (aside from railways) is mechanical engineering. On average, railway, civil and electrical engineering scored the highest. The E.U. has a slightly higher desire across the board for multidisciplinary educational backgrounds such as economics and law.

Table 4.12 and 4.13 report the desired personal skills and characteristics of graduates. There are several similarities between the E.U. and U.S. as evidenced by problem solving, analytical and technical skills, and the ability to work in a fast paced work environmental as among the most desired skills or characteristics of new graduates as they enter the workforce.

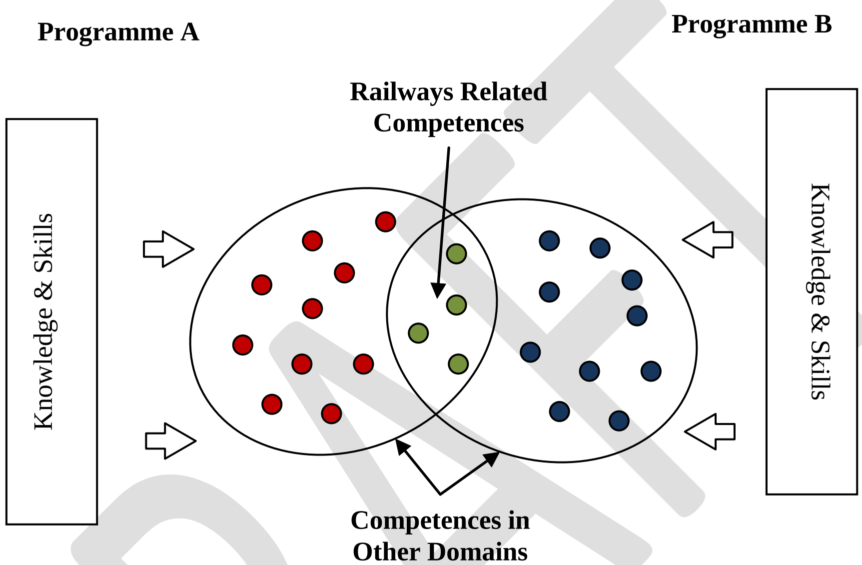

Figure 4.22 - Competences from Different Programs

Table 4.10 - Highest Ranked Types of University Education

	United States	European Union	Other
1st	Civil (4.08)	Railways (3.79)	Railways (4.56)
2nd	Railways (3.99)	Mechanical (3.48)	Civil (4.12)
3rd	Electrical/Electronics (3.21)	Electrical/Electronics (3.23)	Electrical/Electronics (3.82)
4th	Mechanical (3.14)	System (3.19)	Computer/Software (3.71)
5th	Communication (2.83)	Economics and Law (2.76)	System (3.65)

Table 4.11 - Beneficial University Education for Railway Industry Rankings

What types of university education would you consider most beneficial for graduates? (1 – Not Important, 2 – Somewhat Important, 3 – Important, 4 – Very Important, 5 – Extremely Important)	United States	European Union	Other	Overall Average
Engineering				
Aerospace	**1.10**	**2.00**	**1.47**	**1.53**
Automotive	**1.37**	**2.00**	**1.71**	**1.69**
Chemical	**1.48**	**1.65**	**1.71**	**1.61**
Civil	**4.08**	**2.65**	**4.12**	**3.62**
Communication	**2.83**	**2.42**	**3.59**	**2.95**
Computer/Software	**3.04**	**2.54**	**3.71**	**3.10**
Electrical/Electronics	**3.21**	**3.23**	**3.82**	**3.42**
Industrial	**2.48**	**2.32**	**2.94**	**2.58**
Materials	**2.62**	**2.35**	**2.71**	**2.56**
Mechanical	**3.14**	**3.48**	**3.24**	**3.28**
Railways	**3.99**	**3.79**	**4.56**	**4.11**
System	**2.76**	**3.19**	**3.65**	**3.20**
Other	**-**	**-**	**-**	**-**
Multidisciplinary Issues				
Economics and Law	**2.39**	**2.76**	**3.06**	**2.74**
Social Science	**2.04**	**2.15**	**2.71**	**2.30**
Marketing and International Relations	**2.31**	**2.38**	**2.94**	**2.54**
Political Sciences	**2.01**	**2.13**	**2.24**	**2.13**
Other	**-**	**-**	**-**	**-**

Table 4.12 - Highest Ranked Personal Skills/Characteristics for Graduates

	United States	European Union	Other
1st	Problem Solving (4.42)	Ability to work in multidisciplinary teams (4.24)	Problem Solving (4.44)
2nd	Analytical and Technical (4.24)	Problem Solving (4.11)*	Analytical and Technical (4.39)
3rd	Ability to work under stress and time constraints (4.20)	Analytical and Technical (4.11)*	Ability to work in a fast pace environment (4.28)*
4th	Ability to work in a fast pace environment (4.14)	Oral and Written Communications (4.07)	Ability to work under stress and time constraints (4.28)*
5th	Oral and Written Communications (4.10)	Ability to work under stress and time constraints (3.77)	Oral and Written Communications (4.11)

** Indicates a tie in score between two categories.*

Table 4.13 - Beneficial Student Traits for Graduates

What types of university education would you consider most beneficial for graduates? (1 – Not Important, 2 – Somewhat Important, 3 – Important, 4 – Very Important, 5 – Extremely Important)	United States	European Union	Other	Overall Average
Education				
University GPA	**3.26**	**3.20**	**3.76**	**3.41**
History of Leadership (e.g.: Academic Activities, Voluntary Working)	**3.27**	**2.91**	**3.18**	**3.12**
University Course(s) in an area close to railway domain	**3.56**	**3.04**	**3.94**	**3.51**
University Degree in Railway Program (Bachelor or Masters)	**3.23**	**2.79**	**3.81**	**3.28**
Previous experience in working (e.g.: Internship)	**3.61**	**3.15**	**3.59**	**3.45**
Previous experience in railway related work (e.g.: Internship)	**3.61**	**3.09**	**3.53**	**3.41**
Other	**1.29**	**-**	**1.00**	**1.15**
Personal Profile				

Demonstrated interest in railways	**3.72**	**3.33**	**3.94**	**3.66**
Mobility and willingness to relocate	**3.63**	**3.30**	**3.39**	**3.44**
Willingness to work outdoors	**3.89**	**2.70**	**3.61**	**3.40**
Willingness to work irregular schedules and long days	**3.84**	**3.09**	**3.72**	**3.55**
Ability to work in a fast pace environment	**4.14**	**3.35**	**4.28**	**3.92**
Ability to work under stress and time constraints	**4.20**	**3.77**	**4.28**	**4.08**
Other	**1.32**	**1.27**	**1.67**	**1.42**
Skills				
Problem Solving	**4.42**	**4.11**	**4.44**	**4.32**
Analytical and Technical	**4.24**	**4.11**	**4.39**	**4.24**
Theoretical	**3.35**	**3.26**	**3.72**	**3.44**
Oral and Written Communications	**4.10**	**4.07**	**4.11**	**4.09**
Leadership	**3.99**	**3.47**	**3.65**	**3.70**
Ability to work in multidisciplinary teams	**4.11**	**4.24**	**4.00**	**4.12**
Other	**-**	**-**	**-**	**-**

4.4.1.3 Step 3 – Course Survey (supply of competence)

This step analysed the educational offerings in railways, in both European Union and United States. The objective was to infer the expected competences that students acquire and check whether they are aligned with the demands placed by the industry.

The review of university rail programs and offerings was provided in Chapter 2. In the European Union, a total of 260 courses and programs were identified while in the United States, the analyses included 19 courses. This demonstrates the large difference in educational offerings between the regions.

The list of available courses in the U.S. is provided in Table 4.14.

Table 4.14 - List of railways courses in the United States

University Name	Course name (in English)
University of Illinois at Urbana-Champaign	Railroad Transportation Engineering
	Railroad Track Engineering
	Railway Signaling and Control
	Railroad Project Planning and Design
	High-Speed Rail Engineering
	Advances in Railway Technology
Michigan Technological University	Railroad Track Engineering and Design
	Railroad Engineering
	Public Transit Engineering and Planning
	Rail Transportation Seminar
University of Kentucky	Railroad Facilities Design and Analysis
	Railroad Operations Management
Vanderbilt	Intermodal Freight Transportation
Memphis	Introduction to Freight Transportation
University of Kansas	Railroad Engineering
University of North Florida	Introduction to Railroad Engineering
North Dakota State University	Railroad Planning and Design
South Dakota State University	Transportation Engineering, Railroad Project Design
University of Maryland	Urban Transit Planning and Rail Transportation Engineering
University of Illinois at Chicago	Railroad Vehicle Dynamics

Each course was analysed based on:

- The contents and syllabus of the course;
- The Program or Department under which the course is taught

Course contents and syllabus provided basic information for inferring the competences the students were expected to acquire. The program and department of the course provided information on the background knowledge and skills the students would acquire. Each course (and program) was labelled with a single domain of knowledge, in function of the department (or faculty). The same reasoning was applied for identifying the competences. The team acknowledged that certain courses (in particular offered in the first year of a program or as an introductory course) typically address more than one competence. For each course either the core competence was identified and labelled accordingly, or the course was defined as "multidisciplinary".

The analysis of the U.S. courses raised two concerns. First, the low overall number of available courses limited quantitative analysis. Second, most U.S. introductory courses were multidisciplinary in nature, as they cover wide scope of topics on surface level. For these reasons, quantitative analyses were conducted only for the E.U., whereas for the U.S. only qualitative analyses were conducted.

The results of the survey for the E.U. courses are displayed in Figure 4.23 and Figure 4.24 and Table 4.15 and Table 4.16). The main conclusion is that major concentration of the courses and programs is hosted on a few areas of knowledge (departments). In the E.U., railways-related courses were found in programs in the area of *railways* (and *transport*) (111 courses), *mechanical engineering* (4 courses), *electrical and electronics engineering* (1 course), *civil engineering* (127 courses), *industrial engineering* (9 courses) and *automotive engineering* (2 courses). In the U.S. the concentration is even higher, mainly due to the limited amount of courses, in *civil engineering* (18 courses) and *mechanical engineering* (1 course).

In the E.U., the topics in most courses (Figure 4.24) are focused on the development of competences on *operations* (149 courses), *rolling stock and traction* (25 courses) and *civil engineering and infrastructure* (16 courses); while in the U.S., most courses are focused on the development of competences on *multidisciplinary issues related to railways* (12 courses), or on *civil engineering and infrastructures* (4 courses). The multidisciplinary nature of the courses in U.S. provides students with exposure of many competences, but it is often at the introductory level. The multidisciplinary nature of rail courses in the U.S. is not surprising, as most universities have only a single course related to the topic making a general introductory course an appealing option. An interesting finding was the lack of courses focussed on the development of competence related to the *environment*, although it could be speculated that in many programs students have at least one general course relating to this competence.

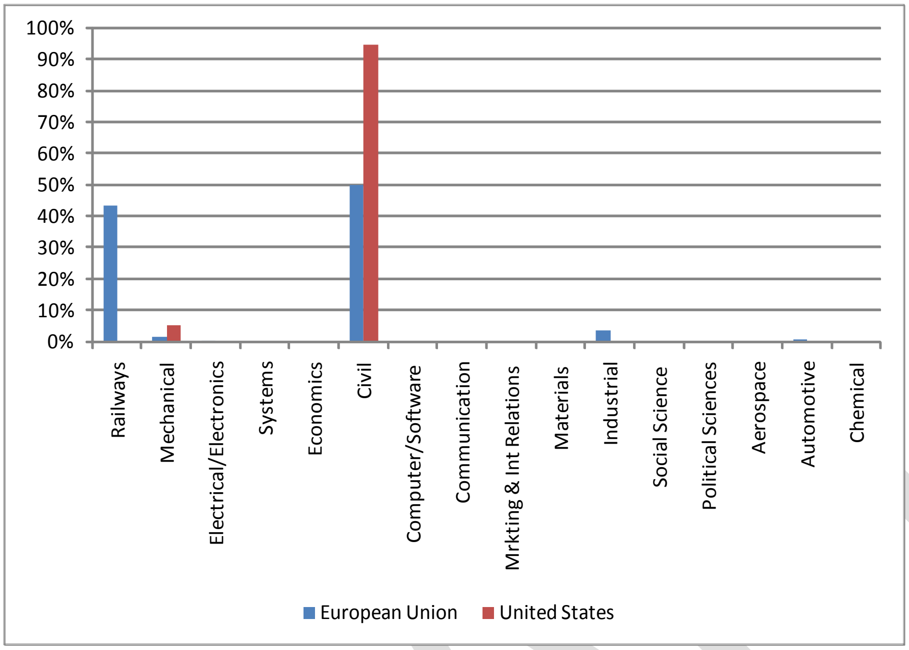

Figure 4.23 - Domains of Knowledge (departments) hosting Rail Higher education courses

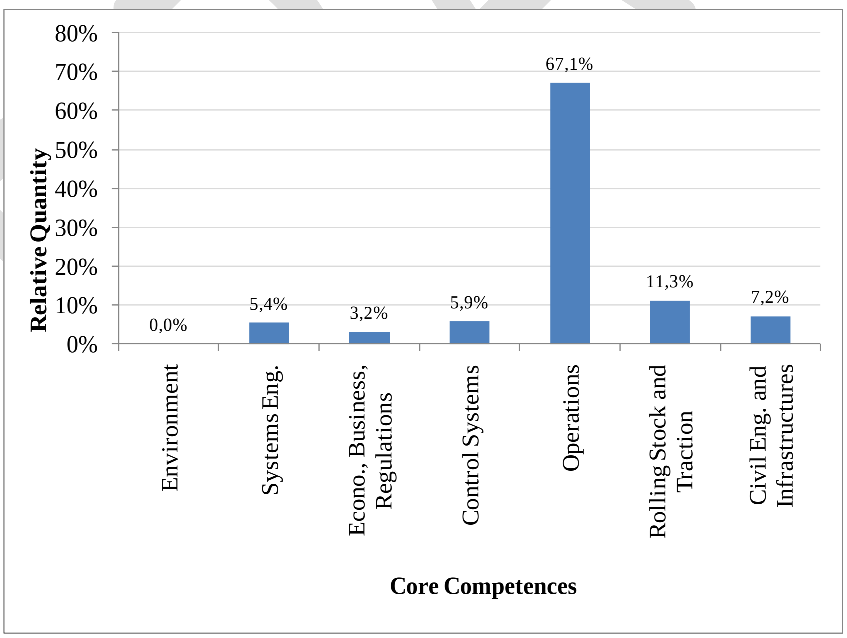

Figure 4.24 - Competences

Table 4.15 - Domains of knowledge (Departments) of Rail Courses

Domains	European Union		United States	
	# Courses	Percentage	# Courses	Percentage
Railways (Transport.)	111	48%	0	0%
Mechanical	4	2%	1	5%
Electrical/Electronics	1	0.5%	0	0%
System	0	0%	0	0%
Economics and Law	0	0%	0	0%
Civil	127	50%	18	95%
Computer/Software	0	0%	0	0%
Communication	0	0%	0	0%
Marketing & Int. Relations	0	0%	0	0%
Materials	0	0%	0	0%
Industrial	9	3.5%	0	0%
Social Science	0	0%	0	0%
Political Sciences	0	0%	0	0%
Aerospace	0	0%	0	0%
Automotive	2	1%	0	0%
Chemical	0	0%	0	0%

Table 4.16 - Distribution of Courses between Core Competence Categories in E.U.

Competences	European Union	
Environment	0	0%
Systems Eng.	12	5%
Econo., Business, Regulations	7	3%
Control Systems	13	6%
Operations	149	68%
Rolling Stock and Traction	25	11%
Civil Eng. and Infrastructures	16	7%

4.4.1.4 Step 4 – Gap Assessment

The analysis of university and industry surveys suggests a gap between the competences demanded by the railway industry and the competences supplied by the institutions of higher educational. The gap is apparent in both the European Union and the United States, although there are differences. The following provides summary of the gap analysis:

- In both regions, there is a likely gap in the competence *environment.* This competence was highly valuated by the railways industry, ranking in first in the E.U. and second in the U.S. however, no courses were found that would develop environment related competences in railways. It could be argued that students may lack competences in this domain, which could jeopardise their labour productivity and competency, but it could be also argued that skills in this area are obtained through other university course which are not specific to railways.

- Also in both regions, data suggests a misalignment between the relevance of the competences in the industry and academia. To assess the relevancy of competence in the academia we consider the number of courses on each competence given by the higher education institutions (and professors). The higher the number of courses on a given competence indicates higher relevancy than other competencies.

- In the European Union a great relevancy is attributed to the competence *operations*, accounting with almost 150 of the courses. Yet, this competence is only ranked in fifth by the industry. Other competence relevant is the *rolling stock and traction* (with 25 courses); yet, industry gives very low relevance, ranking it in sixth place. There were no courses available for the top ranked competence by the industry (*environment)* and the second ranked competence (*systems engineering)* appeared in fifth place in academic offerings.

- In the U.S., a gap analysis could not be undertaken because of limited course offerings in U.S. universities. As most courses are multidisciplinary in nature, it is expected that students get exposure to most competences, the only exception being the competence environment that seems to have low relevancy in most courses. However, U.S. students are likely to be less proficient than the E.U. students, simply because here there are no dedicated courses for almost any competence.

- Analysing the areas of knowledge (departments), one conclusion is that most courses concentrate on limited domains of knowledge. In the E.U., courses were found in six domains (out of sixteen), and two of them covered more than 90% of the courses (Civil

Engineering and Railways). The same occurs in the U.S. Civil Engineering covers 95% of the courses, although the low overall number of courses limits the relevance of analysis. The educational offerings are in contrast with the industry that is demanding competences in a vast array of domains of knowledge, such as mechanical engineering, electrical and electronic engineering or systems engineering. The absence of courses in these areas may evidence a lower level of competence of students in certain key areas.

- A higher relevance of the competence *civil engineering and infrastructure* was expected in the E.U., since the majority of the courses are taught in civil engineering programs (total of 127 courses). Furthermore, the predominance of rail related courses in this type of programs contrasts directly with the low relevance of this competence by the industry, which may indicate a misreading of the market needs. Conversely, in the U.S., this was the top ranked competence which is aligned with the fact of the large majority of the courses are taught in civil engineering programs.
- In the E.U., the domain (department) of railway transportation, with a total of 111 courses. Bearing in mind that these are courses customised for railways, we were expecting a lower competence gap, which may again indicate a misreading of the market needs.
- In the U.S., the assessment of a gap is limited by the small number of courses that are offered and as a result a clear picture on the actual competences being earned by the students is difficult to determine.

5 Innovative Teaching Approaches in Railway Higher Education

5.1 Global Education Program Formats

As the research team explored rail transportation programs it be apparent that there would be exciting opportunities to develop initiatives that would draw on the experiences of universities in both the E.U. and U.S. As the rail transportation industry involves several disciplinary and it is more globally focused, our educational programs must also provide a global or international focus. One of the first steps in the process is to understand what is meant by global education, what methodologies can be used, and what tools are needed to achieve the desired outcomes. According to Alan Parkinson[42], students with global competence should be equipped with a wide set of abilities. The most important abilities include:

- appreciation to other cultures;
- proficiency in working in or in directing a team of ethnic and cultural diversity;
- ability to communicate across cultures;
- effective dealing with ethical issues arising from cultural or national differences; and
- engineering practice in a global context, whether through an international internship, a service-learning opportunity, a virtual global engineering project or some other form of experience.

To prepare the students with these abilities, emphasis should be placed on three areas of education:

- foreign culture appreciation and understanding;
- communicating in foreign language; and
- real-world practice in a global context.

Based on Parkinson, an individual program that only focuses on one of these aspects, such as on campus foreign language training class, is insufficient. A complete program should combine all

[42] Alan Parkinson, J. Harb, S. Magleby, 2009, "Developing Global Competence in Engineers: What does it mean? What is most important?" ASEE paper No. AC 2009-571.

three aspects. If this is impossible, a program system constituting different levels of activities should be established, and the activities should involve training or education that can compensate for missing elements.

Many innovative approaches toward global education in the engineering field have been developed and these approaches can be grouped into several categories. Some of the features and existing program formats were introduced by Alan Parkinson[43], James L. Melsa[44] and others. Lautala and Ma, for instance, compiled a number of innovative approaches for teaching and training into a useful summary (Table 5.1).[45] Although the table is not all inclusive, it provides a basic introduction to the common approaches currently used to global education.

Table 5.1 - Existing Program Formats for Global Education

Program Formats	**Description**	Summary
Traditional international activities	Visiting lectures by foreign visitors, international conference, visiting scholars, foreign culture course, foreign language training, enrolling international students, bilingual teaching.	• The most extensively used methods. • Easy to organize and easier to recruit students. • Have an introduction to foreign culture and meet the local students
E-learning & E-teaching	Teaching by foreign universities lecturers through internet-based tools	• Economic way for the students learn foreign technologies • Limited exposure to foreign culture
Virtual global l - class	Students from different universities study together by using internet-based tools in a virtual global classroom.	• Good opportunity for students to learn about global issues. • Exposure to foreign culture is limited.
Short-term study - abroad programs	Extended field trip, summer program or mentored travel: Students travel to one or several countries and visit companies and/or universities for a tour and/or lectures between one to several weeks under the guidance of a faculty member.	• Brief exposure, but an efficient way to attract the students to participate in more extensive programs

[43] Alan Parkinson, 2007, "Engineering Study Abroad Programs: Formats, Challengers, Best Practices," Online Journal for Global Engineering Education, 2 (2), Art. 2.
[44] James L. Melsa, David Holger, and Loren Aachary, 2002, "Achieving a global academic industrial network for students and faculty," Managing in the next society, Perte Drucker.
[45] Pasi Lautala, Chao Ma, 2011, Railway Education Today and Steps Toward Global Education, Paper accepted to Joint Rail Conference 2011, Pueblo, CO, March 16-18, 2011.

	Internship or Co-op: students work abroad for a company or at an international branch of a U.S. company.	• A good approach for the real-world practice and brief exposure to industry issues.
	Research abroad: students travel to an foreign laboratory and conducts research under the guidance of a faculty member, etc.	• Good approaches for real-world problem solving. • Team work typically included. • Deeper exposure to foreign culture.
	Project-based learning: students travel abroad and are immersed in another culture via a project connecting technology and local society.	
Long-term study-abroad programs	Exchange: students from the two universities involved are exchanged for a period and take regular courses in the host university. Degree awarded by their home university.	• A popular study abroad program format. • Credits, reorganization and exchange as well as a parity exchange must be coordinated. • An in-depth exposure to living abroad on campus.
	Dual degree: the students obtain one degree from the home university and another one from the foreign university during a period of study abroad.	• Most difficult one for the students to fulfill. • Mostly for graduate-level programs. • An in-depth exposure to living abroad
Long-term on campus programs	Partner sub-contract: the home university cooperates with a foreign university and contracts for courses to be taught to students of the home university.	• On-campus foreign course study rather than studying abroad. • The students always are taught in English. • The exposure to foreign environment is eliminated. • Varieties of international programs can be organized easily. • More global experience opportunities are offered for the students from both campuses or universities
	Extension: the home university operates a pseudo-extension campus in the other country at a permanent facility.	
	Branch campus: the home campus works together with a branch campus in foreign country.	
Others	Combination of the previous formats	

The second component of a successful global education is understanding different learning styles, so a proper set of tools and activities can be used in the programs. *"How People Learn"* (HPL) was founded on a review of recent research in cognitive science and it describes the four principles that should be included in the design of learning environments. The principles include:

- **Learner Centered**: takes into account the learning styles, attitudes and unique characteristics of users; recognizes the prior knowledge and skills that users bring to the learning environment.

- **Knowledge Centered**: provides opportunity for hands-on, learner-driven, interactive learning that leads to students learning with understanding, rather than acquiring disconnected sets of facts and skills. The goal is a mastery of concepts and "transfer of learning" that can then be applied elsewhere.

- **Assessment Centered**: finds ways to monitor progress; not just a test at the end; allows for feedback along the way.

- **Community Centered**: considers the context in which learning takes place; promotes a sense of community through shared goals and values.[46]

HPL transforms the teaching from traditional teacher-centered to learner-centered with more focus on self-learning and active-learning. Active learning can be defined as any instructional method that engages students in their own learning process by encouraging them to think about what they are learning and how well they are learning it.[47]

While it is not the objective of this research project to develop a teaching strategy for rail higher education, it must be recognized that institutions should incorporate methodologies and tools that provide a close alignment with today's learning styles. Some of the innovative methodologies include problem, project and challenge-based learning and collaboration, and context based learning styles. Specific tools and technologies that have played a major part in the expansion of new learning styles include simulators, virtual environment based games and on-line courses.

5.2 Teaching Railway Engineering

Teaching railway engineering differs from teaching many other fields of technology. This is caused by the fact that in a railway system all fields of engineering are interconnected and as a

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[46] Triveni Kuchi, Rebecca Gardner, and Roberta Tipton, A Learning Framework for Information Literacy and Library Instruction programs at Rutgers University Libraries, http://www.rci.rutgers.edu/~kuchi/files/Recommendations%20of%20the%20Learning%20framework%20Study%20Group.pdf

[47] Robert J. Roselli, Sean P. Brophy, Effectiveness of Challenge-Based Instruction in Biomechanics, Journal of Engineering Education, Oct. 2006. 311-324

result teaching railway science must follow an interdisciplinary approach. In addition, while railroad research and teaching railway science are academic, the railroads are a field of practical application. TUNRail investigated the field from engineering / transportation perspective, where students must have a fundamental knowledge of rail related aspects of civil engineering (permanent way, structures), mechanical engineering (rolling stock), electrical engineering (signaling, electric traction), and computer science (signaling, control systems). All these areas of engineering together support the process of operation where they interact in several, often quite complex ways. In several publications, this fact is visualized by a railway systems triangle in which the three major technological subsystems are represented by sub-triangles arranged around a central triangle that represents the operating rules and procedures (Figure 5.1).

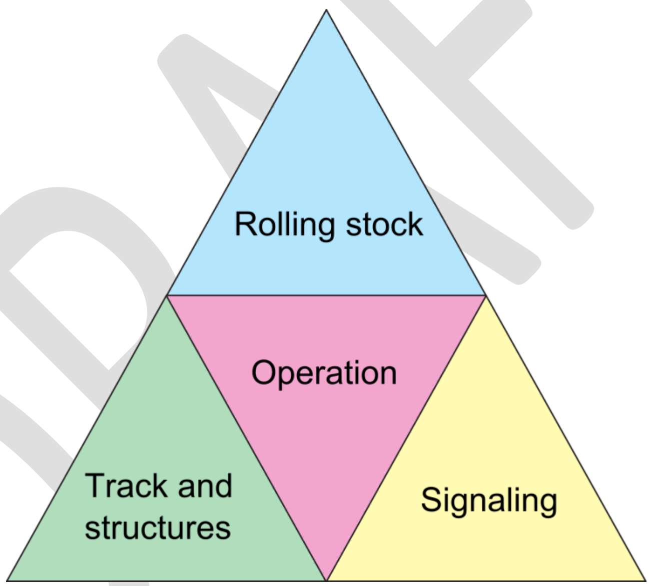

Figure 5.1 - The railway systems triangle

The recognition of this complex interaction is crucial for understanding a railway system. Just teaching the different subsystems separately would not be sufficient to provide an understanding of interconnectivities. Instead, we need teaching methods and technologies that enable the students to experience the interaction of these subsystems in the operating process. One of the traditional approaches to study the complexities has been to use railway operations laboratories. While such laboratories have existed for decades, they have recently gained importance by the integration of digital control, computer and internet technologies. A second development is the increasing use of rail traffic control simulations in higher railway education. Beside the engineering aspects, to understand the complex interdependencies between the different subsystems of a railway system, students also need a fundamental knowledge of transportation economics and management. This can also be supported by project-oriented work using railway operations laboratories and simulations.

5.3 Railway Operations Laboratories

Basically, a railway operations laboratory is a model railway built in laboratory style, and controlled by real-size control stations, i.e., interlocking machines, relay panels, and dispatcher work stations. Figure 5.2 shows photographs of a typical layout. In modern laboratories, trains are digitally controlled using Digital Command Control (DCC) technology. The control system controls train movements by electronically simulated accelerating and braking profiles that meet the performance of real trains depending on the movement characteristics of the train consist. This allows the users to establish timetables with the same scheduling software and Train Performance Calculators (TPC) as used in real railway traffic. In signal-controlled areas, trains run automatically in accordance to signal aspects and timetable data. Shunting moves and train moves authorized by written authority are controlled by Walk Around Controls (WAC).

While most layouts are built in HO scale (1:87), the distance is scaled down to 1:200 or even 1:250 to save space. One of the advantages of this compressed distance scale is that model turnouts which are normally designed with a diverging angle much sharper than on a real railway will come down to a more real geometry. The speed profiles of the trains are also scaled to this compressed scale. When watching a laboratory session at the first time, the trains appear seem to run too slow but they are running at a correct speed according to the compressed distance scale. The largest railway operations laboratories in Europe are at the Universities in Dresden and Darmstadt. While the Dresden laboratory has a total track length of 1300 m with 185 switches based on a compressed scale of 2:200, the Darmstadt laboratory has a total track length of 900 m with 260 switches based on a compressed scale of 2:250[48].

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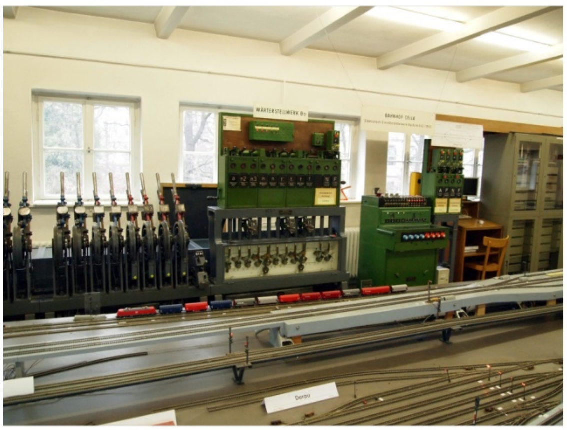
[48] Pachl, J.: Ausbildung von Eisenbahningenieuren – Stand und Perspektiven. Eisenbahningenieur-Kalender 2009, p. 285—294

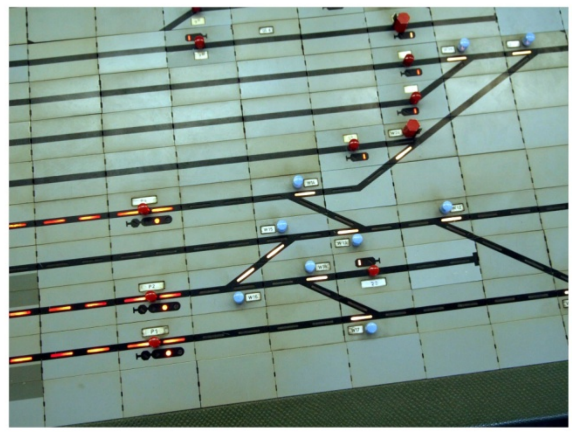
In modern laboratories, control stations are connected to the field elements by a standardized electronic interface. Even old lever frame machines communicate with field elements by digital signals sent through these interfaces. This allows the management of the laboratory to switch control of a specific part of the layout between different control technologies. Another benefit is to produce a record of all control action for later evaluation by the teaching staff. It is very typical for a railway operations laboratory to provide different generations of control technology. There is usually at least one example of an old pre-war lever frame machine. This is not done for nostalgic reasons rather the old technology is invaluable for the understanding of the fundamental interlocking and block control principles. Beside the signal control technology, a laboratory also provides all communications technology needed for traffic control.

Total view of the layout

Operator in the dispatching office



Old leverframe interlocking machines



Details of a push button control panel

Figure 5.2 - Photographs of the railway operations laboratory at the Berlin University of Technology[49]

Railway operations laboratories are used for different kinds of teaching. The most typical use is to let students run operating sessions in which they staff control stations and run scheduled traffic for a couple of hours in accordance with the operating rules. This also includes doing all the paperwork, telephone and radio communications. To prepare the students for these operating sessions, they get specific lectures on operating rules. After a number of sessions, the students become quite familiar with the regular traffic and they have experienced several types of control technology, technical failures, maintenance works, and emergency situations may be part of the sessions. This provides almost unlimited resources for training ideas. Students, even those who

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[49] Author of the photographs: Jörn Pachl), for more information on that laboratory, see www.ebuef.de

were skeptical at the beginning, always give a very positive feedback and consider the laboratory work an extremely valuable part of their railway studies. They also confirm the benefits of a modeled track layout over a pure simulation.

In addition to this traditional use of a railway operations laboratory, there are also interesting possibilities for project oriented work. An interesting example can be found at the Aachen University, where the laboratory network is used for role playing at the interface between train operating companies and the infrastructure manager[50]. For this, there are several groups of students, each of them representing a train operating company. Each group develops a transportation plan for a given demand, establishes a desired timetable and orders the required train paths from the infrastructure manager. The infrastructure manager is either represented by another group of students or by teaching staff. The infrastructure manager will perform the scheduling process based on the ordered train paths. In case of train path conflicts, the infrastructure manager will try to find a solution with the involved train operating companies following the procedures used in the German railway network. There is also a simplified trackage fee system with access fees depending on routes and train classes. So, the groups representing train operating companies are forced to make enough revenue to pay the trackage fees for their train system. As the result, the students get a timetable that is feasible and that everybody has agreed to. This timetable is then used for an operating session in the laboratory. Everybody involved in transportation planning and the scheduling process experiences how a timetable really works.

New users of railway operations laboratories outside the railway education field have also been identified. Running an operating session in a laboratory is pure teamwork and a perfect training for human interaction in the control of a complex system. This has caught the attention of people teaching soft skills. Today, at some universities, special laboratory sessions are offered for people without any background in railway technology. The objective is not to comply with operating rules to the last detail but rather to experience teamwork and interaction. For this, the students get some introductory lectures on the basics on railway operation followed by a practical tour on the layout in which the handling of the different control systems is

[50] Wendler, E.; Grudzenski, B.: Planspiel Trassenmanagement – Ein Aus- und Weiterbildungskonzept für die Fahrplanerstellung unter den neuen Bedingungen des Schienennetzzugangs. Güterbahnen (4) 1/2005, p. 33—36

demonstrated. During the session, the students are assisted by teaching staff or railway students. The feedback after such sessions brought the result that the old lever frame machines have the greatest effect for the teamwork experience as they require communications and interactions in which one operator often relies on the correct working of another operator.

5.4 Rail Traffic Control Simulations

Rail traffic control simulations simulate railway traffic on the level of the control system, i.e., the user operates a prototype-like user interface of an interlocking or dispatching system in real-time mode. In this way, rail traffic control simulations differ significantly from rail traffic simulations used in capacity research that run in time-lapse mode and do not simulate the operator's interface. The first rail traffic control simulations appeared in the early 1990s. In the late 1990s, they had reached a state of development that met the requirements of professional training. Interlocking and dispatching simulators are now a standard training tool used by railway companies. At the beginning, prices for such simulators were so high that universities had hardly a chance to use such systems for students training. Later, some manufacturers offered slightly simplified consumer versions that are still very close to the prototype and offer nice opportunities for university education. Some universities even developed their own simulators.

Rail traffic simulations have recently changed teaching in railway operations in several ways. There are three areas in which rail traffic simulations can be used to improve teaching. First, simulations can be used as demonstrators to visualize specific situations in lectures on railway operation and signaling. However, while this is a valuable addition to traditional slide presentations, it is also quite time consuming. So, running simulations during lectures should be used with care. In many cases, best use of simulations in lectures is to take cutouts of screenshots of specific situations prepared offline and to integrated them in presentations slides. Figure 5.3 shows two typical lecture slide produced this way to demonstrate specific interlocking functions.

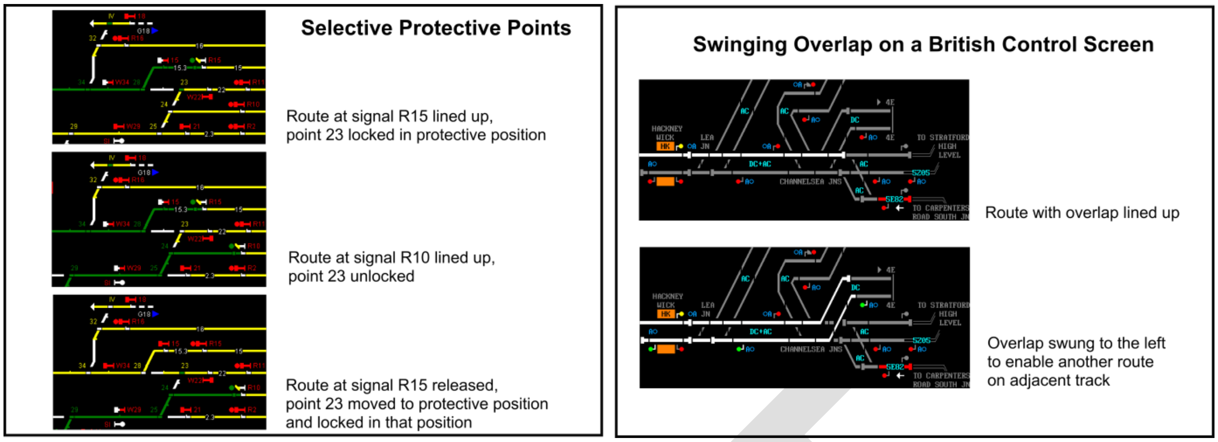

Figure 5.3 - Examples of lecture slides produced with rail traffic control simulations[51]

The most challenging use of simulations is to let students run simulations to experience rail traffic control. This has proved to be the most effective way to prepare students for laboratory work. The interesting aspect of doing this is the ‘serious gaming’ effect. By using simulations, the subject of operating rules is learned with some fun factor and students get an incredible level of knowledge on the process of rail traffic control and the operating rules of a specific railway. The same effect is known from other industries and it is the background behind the growing serious gaming movement. Beside rail traffic control simulations that can only be run on a single computer by one student, there are now also powerful simulations that allow the user to connect control stations via internet protocol forming networks in which operators have to interact with each other. The most advanced simulation software of that kind currently available is the SimSig simulation system from www.simsig.co.uk that follows British operating practice. Another popular software is the German simulation ESTWsim from www.estwsim.de. This brought up the idea of virtual railway operations laboratories, i.e., railway operations laboratories without the physical model railway part, is described in several papers.[52]

5.5 Recent Developments in Innovative Laboratory and Simulator Teaching

Several recent developments in computer technology have created promising opportunities for the use of laboratories and simulations. One development is to connect a railway operations laboratory to simulations, another development is to connect laboratories and simulations to the

[51] Author of the slides: Jörn Pachl)

[52] Jacobs, J.; Wendler, E.: ESTW-Simulationssoftware in der Eisenbahningenieurausbildung. Signal+Draht (103) 3/2009, p. 31—36

internet to create distributed learning environments. One concept for a connection between laboratories and simulations is to extend the modeled network of a railway operations laboratory by connecting it to a virtual network controlled by a CTC simulation.[53] Trains leaving the modeled area may continue their run in the virtual network and vice versa. A train that is going to move from the modeled area into the virtual network, would leave the modeled area by entering a hidden storage yard. At the same time, the train appears as a simulated train on the control screen of the CTC simulation. In the opposing direction, a train leaving the virtual network will initiate a train waiting in the hidden storage yard to start moving and to appear on the visible part of the modeled area. While the tracks of the modeled area may be controlled by local control stations, the virtual area has to be CTC territory. Since, in a real operations control centre, the dispatchers are far away from the controlled railway lines, a CTC simulation provides a close to reality feeling for controlling the virtual network. Another concept of connecting laboratories and simulations is to use a locomotive cab simulation to control trains on the model layout. By doing this, the train driver's role will become part of the laboratory work. The window picture of the cab simulation could either be produced by a camera mounted on a locomotive (model locomotives with integrated cameras are already commercially available) or by a virtual reality environment that just takes the locomotive position from the model layout but generates a more real looking virtual picture for the cab simulator.

The intention of connecting laboratories and simulations to the internet is to run operating sessions with students working at locations that are far away from each other, i.e., that are located in different cities or even countries. This would allow students to take part in session without need for expensive and time consuming travel. A first step could be to distribute an online track chart of an operations laboratory displaying current train positions via internet so that students at other universities can watch an operating session and maybe even get involved in decision making. A more advanced solution would be to control parts of a laboratory via internet from a remote CTC control station. In laboratories that already have an extension into a virtual network, remote control of parts of the virtual network would be easy to implement. Technology to connect CTC simulations via internet already exists. Internet-based remote control of parts of

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[53] Holland-Nell, H.; Ginzel, Th.; Demitz, J.: Weiterentwicklung des Eisenbahnbetriebslabors der TU Dresden. Signal+Draht (99) 11/2007, p. 23—27

the modeled area is more complicate, however. One of the most interesting aspects of distributed control of laboratory sessions is that students in one country can take part in laboratory sessions in another country (or even on another continent) and by doing this experience foreign operating practices.

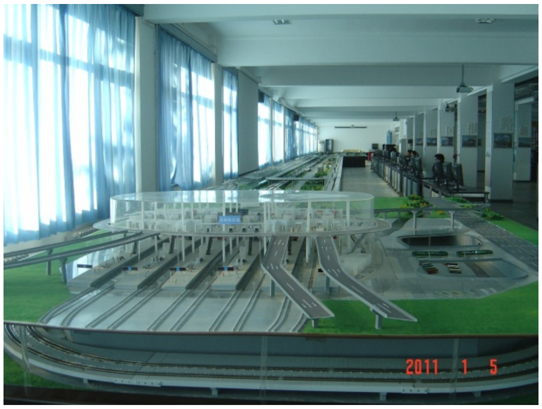
5.6 Beijing Jiaotong University Simulation Software

The School of Traffic and Transportation, Beijing Jiaotong University have also developed software for the railway industry to simulate operation and dispatch and with a few modifications the software can be used for teaching and laboratory simulations. The software simulates real world operations issues such as train operation and dispatching systems, dispatching decision support systems for railway marshaling stations, dispatching planning system for large passenger and freight stations, as well as train diagram of reticulation lines computer planning system.

Students will make timetables on computer using data of given railway line (such as Beijing-Shanghai railway) given rail traffic demand, time requirement of passenger car use, etc. Also they can participate in different roles to make co-operation simulations of train dispatching system such as simulated train receiving and departure.

China’s railway transportation network uses routine plans containing information including loading and unloading plans with different freight categories and destinations, train dispatching schedules, train taking over plans of divisional stations and locomotive utilization plans, along with other information. These plans are made according to monthly transportation plan, transportation technical plan, train formation plan, timetable, comprehensive operation scheme of railway transportation, and adjusting measures of traffic flow. The routine plans include a daily plan, shift plan (12-hour) and stage plan (3 to 4-hour). The railway station is responsible for making shift plan and stage plan. In the laboratory, students make shift plan and stage plan simulation on computer. Students can then arrange locomotive operation, passenger train operation, freight train operation and adjust them as needed.

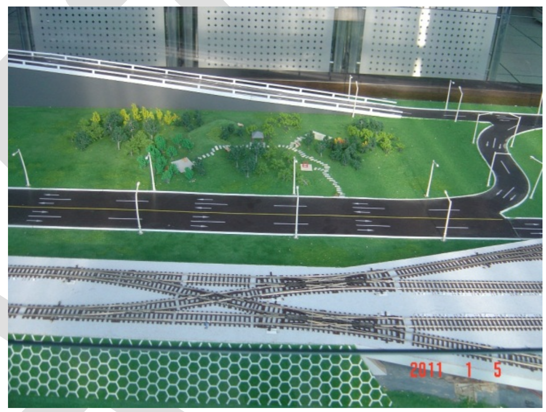
Transportation Simulation Laboratory, as shown in Figure 5.4, is part of the Experiment Center of Traffic and Transportation and was built to simulate real traffic. The model is based on Beijing-Tianjin Passenger Dedicated Line for students to simulate dispatching on PDL.



Total view

Tracks and Signals

Railway station



Turnouts

Figure 5.4 - Transportation Simulation Laboratory at Beijing Jiaotong University[54]

Students construct a train operation plan, EMU utilization plan, and station tracks utilization plan, and then transmit the plans to a model system using the computer experiment simulating system. The control system of model will operate trains according to the plans and provide dynamic feedback. Students will make train operation adjustment plan based on feedback data and commit it to the mode system. This allows students to see how the rolling plans can be made and optimized, how to adjust train operations, and supervise dispatching in real time.

5.7 Railway Infrastructure Education

In the U.S., railway engineering courses are typically course offer in departments of Civil Engineering and concentrate on railroad infrastructure systems. While the tools and procedures

[54] Photographer: Mei Han

used for track design and engineering are well established, their use in university settings has been somewhat limited. The U.S. rail industry expects high levels of practical applications from graduates and therefore, some of the classes have also been oriented to learn and understand the tools and skills needed in everyday railroad development and operations. The following paragraphs provide two examples, how Michigan Tech University (MTU) and University of Illinois, Urbana-Champaign (UIUC) incorporate practical tools and approaches to the educational process.

5.7.1 Railroad Track Engineering and Design Course - Michigan Tech University

Michigan Tech has offered a graduate level course in Railroad Track Engineering and Design since 2008. The course introduces students to the design and development of construction documents for railroad projects, especially to the construction of a new, or modification of an existing track. The course takes a hands-on approach where assigned readings, interactive lectures, homework assignments and other instructional materials will be applied by participants to incrementally complete design exercises and eventually a real-life rail project with help of two commonly used CAD software, MicroStation and Geopak, The students will work both individually and in 2-3 person teams throughout the course and perform assignments needed to complete the project from the initial idea, through the design to the delivery of final plans for construction. The project steps will include taking an existing track layout and topography in a design software, creating a design for modified layout and developing construction documents which will include plan sheets, typical sections and general cost/quantity estimates (Figure 5.5). By the end of the program, students will have a basic understanding in the fundamentals of the track components, track design principles and criteria, track construction process and estimating the basic project costs. They have also gained hands-on experience in how to use MicroStation and Geopak software in the design part of the project.

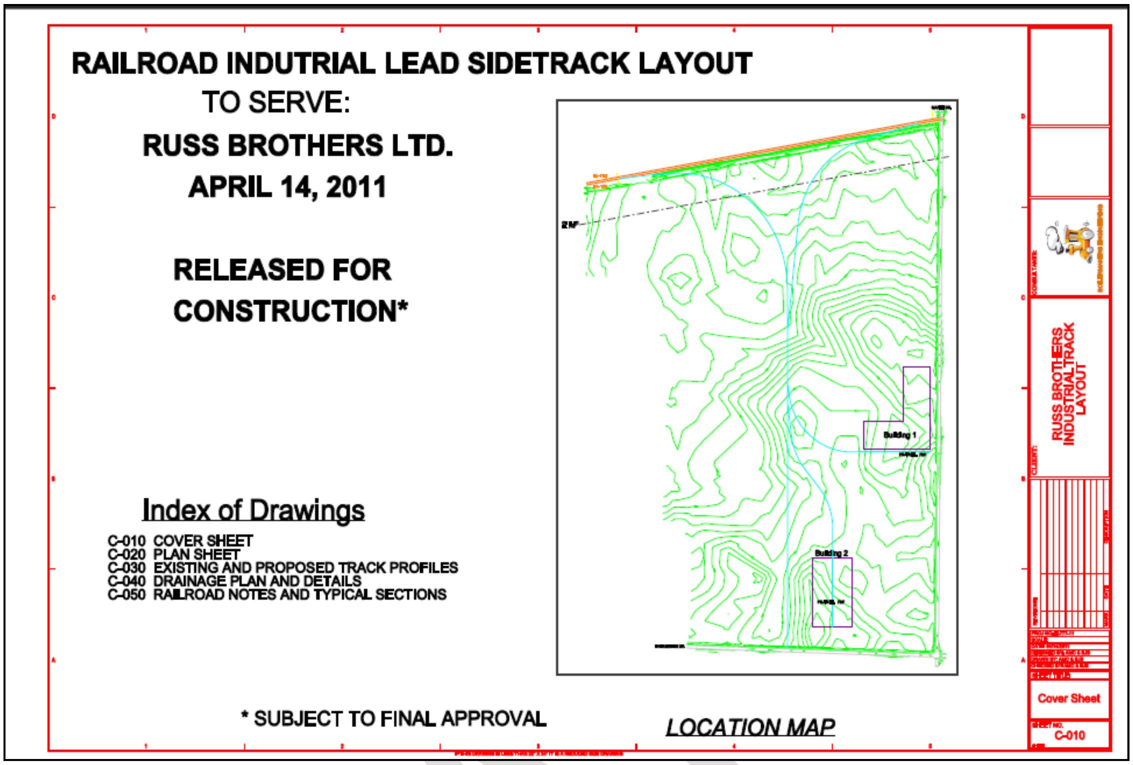


Figure 5.5 - Sample Plan Set Cover Sheet of Railroad Track Design and Engineering Final Project

The approach that reviews engineering criteria and principles in the classroom, followed by immediate implementation in professional CAD software has received enthusiastic response from the students. It allows them to apply the learned knowledge without delay and provides a hands-on approach to the learning, which is preferred by most of today's students. Industry employers have also been appreciative for the approach, as it allows them to quickly review the design capabilities of students and provides evidence that they master the design and production aspects of a typical track construction project.

5.7.2 Infrastructure Engineering at University of Illinois, Urbana-Champaign

The Rail Transportation and Engineering Center (RailTEC) at the University of Illinois at Urbana-Champaign (UIUC) employs several innovating teaching methods and exercises. At least once per academic year, the faculty from RailTEC take the students into the field to work on operational railway infrastructure at the Monticello Railway Museum in Monticello, Illinois, shown in Figure 5.6 below. This opportunity allows the students to serve the museum by helping perform track maintenance, and it also allows the students by enhancing their classroom experience and teaching them what types of maintenance activities are required in the real world, through performing the track maintenance themselves. This activity has been tremendously successful over the past six years, and continually receives good reviews from both the faculty, students, and the railway museum. Additional field visits and tours allow the students to see railway dispatching centers, track construction projects, and new capital projects, and these occur in conjunction with courses that focus on the aforementioned topics.

Figure 5.6 - UIUC RailTEC performing field work at Monticello Railway Museum in Monticello, Illinois

UIUC students are also exposed to software programs that are not traditionally used in other transportation courses in North America. Examples of these software packages are the Association of American Railroads (AAR) Train Energy Model (TEM), used to calculate fuel consumption and train resistance, Rail Traffic Controller (RTC) (shown in Figure 5.7), used to model network capacity, as well as Bentley Systems MicroStation, used to design railway infrastructure. Each of these software programs are utilized by students in research projects with the railway industry, and those students are typically called upon to teach the software in the appropriate railway engineering course.

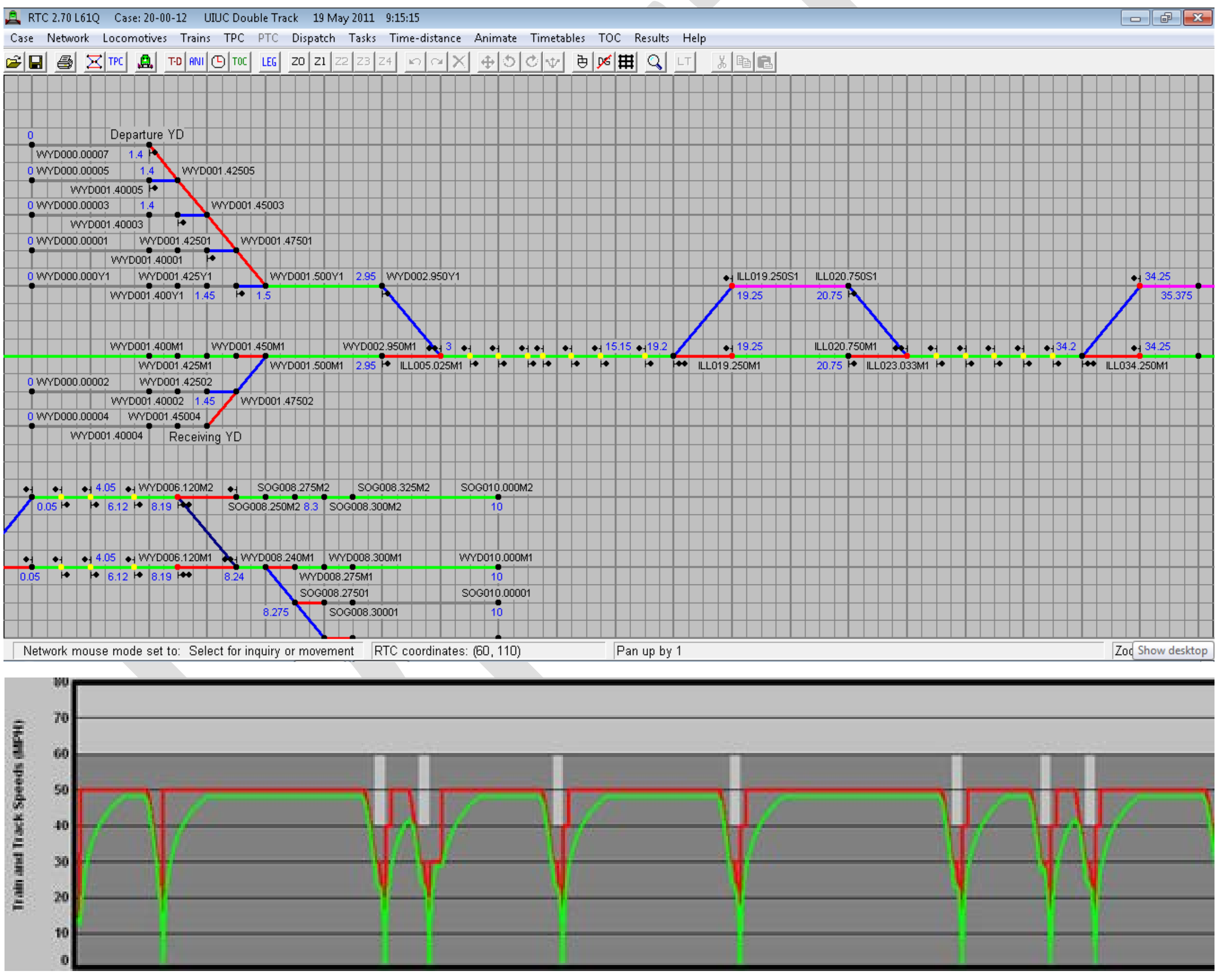


Figure 5.7 - RTC Software user interface showing route planning and simulation train speed data

A design project that transcends two of the railway engineering courses at UIUC has recently been developed. The project focuses on both the micro and macro level of railway infrastructure design. The macro level of the project is conducted in a course known as "Railway Project Design and Construction", where the students focus on determining the appropriate alignment from various alternatives, perform some elements of track design, and scope out all of the project management and construction management steps that are needed to see the project through to completion. The micro level design project accompanies a class titled "Railway Track Engineering", and involves the design of track components (sleepers, ballast depth, etc.) as well as curve geometry. These interconnected design projects have received very favorable reviews, and have served to link the two courses and encourage enrollment in consecutive railway engineering courses.

5.8 Use of web technologies in railway education and training

Web technologies have been used in railway education and training to facilitate e-learning practice and to develop and maintain web-based rail portals for knowledge sharing. “Safety on/or along the track” was a two year project (01 August 2009 – 31 July 2010) led by UIC with partners: Railinfra opleidingen, MAV Baross Gabor training centre, DB Training, funded by Leonardo da Vinci programme of the European Commission that aimed to develop *e*-learning material for safety of personnel working on/along the tracks.[55] Specifically, the intended outcomes from this project were to:

- develop European best-practice guidelines to be used in developing an e-learning module for safety of personnel working on or along the tracks ;
- develop an e-learning module based on guidelines produced;
- provide access to partners to the *e*-learning material developed.

In developing the e-learning module a methodology by David E. Stone has been used.[56] Important elements that have been considered were as follows:

- Use Web 2.0, social media, e-networking, user determines what and how to learn;
- Make e-learning easy for the audience, always blended with training in classroom;

[55] Safety on/or along the track – Project website, (2009 - 2010), www.bgok.hu/safety - accessed on August, 7, 2011.
[56] David E. Stone & Constance L. Koskinen (2002) Planning and Design for High-Tech Web-Based Training, Artech House, Inc. Norwood, MA, USA ©2002, ISBN:1580533159

- Provide options for language;
- Short e-learning module, short text with emphasis on pictures,
- User friendly navigation though the portal and afterwards – one button – one click;
- Use audio elements to make it lively;
- Provide guidance – help menu;

The National French Railways Company (SNCF) have recently opted for a change management approach within the company allowing project managers to share their knowledge and experiences through an IT device called “knowledge server” . The model chosen for the purposes of this project is an ontology that represents change management knowledge in the formalism of conceptual graphs.[57] Once implemented, this ontology is used as a structure for a change management knowledge server. By “knowledge server”, “an information system is meant that allows users to improve their practice”. In other words, a knowledge server is a system which, instead of simulating human reasoning as an expert system would do, provides the user with some support for reasoning by analyzing the knowledge the user needs. As the possible strategies for change management are diverse and strongly context dependent, it is a means for encouraging users’ reasoning and action, instead of guiding them towards a single recommendation resulting from automatic reasoning.[58] The knowledge server is equipped with user friendly interface, as shown in Figure 5,8 and functions as web based portal for knowledge failing and sharing.

[57] Sowa, J. (1984). Conceptual Structures : Information Processing in Mind and Machine. Addison-Wesley.
[58] Remillieux, A., Petitmengin, C., Ermine, J.-L., Blatter, C. (2010). Knowledge Sharing in Change Management, A Case Study in the French Railways Company. Journal of Knowledge Management Practice. Vol. 11, N°2, June 2010.

Figure 5.8 - A Screenshot of Web Based Portal for Knowledge sharing in SNCF

5.9 Research Project

5.9.1 Skillrail - Education and Training Actions for High Skilled Job Opportunities in the Railway Sector

The SKILLRAIL project aims to contribute to the enhancement of the transport sector by fostering a better match between the human resources needs and the offer of skills to make railways a more competitive and innovative sector.[59] Specifically, this FP project is aimed at designing and launching a sustainable framework, to be called E.U.RAIL "European University of Railway", for creation, dissemination and knowledge transfer within the railway sector in Europe. E.U.Rail is intended to be a virtual training environment ensuring concentration of high-level knowledge and expertise in one single location.

[59] SKILLRAIL project web site, 2011, www.skillrail.eu – accessed on August, 8, 2011

Driven by the needs of the rail industry the European University of Railway- E.U.Rail is envisioned to provide the necessary conditions for disseminating social and industrial benefits of rail training and education and develop a highly-qualified railway community of tomorrow.

5.9.2 **RiFLE - *Rail F*reight and Logistics Curriculum**

The learning style is dependent on the teaching and training policy and practice of the Higher Education Institutions (HEI). The organization and development of the courses specify to a certain extent the method of teaching which suggests the learning style. Recently, universities have been promoting innovative teaching and learning through multidisciplinary approaches. An example of such an initiative in the rail higher education is the RiFLE project funded by the ERASMUS programme of the European Commission.[60] RiFLE stands for Rail Freight and Logistics Curriculum Development and combines two different sectors – railways and logistics. Specifically, the aim of this project is to develop and run a joint MSc programme that teaches how rail freight services could benefit from lean logistics principles and how logistics chains could benefit from the railways as an environmentally friendly transport mode. The programme will be run in parallel in four European HEIs and include compatible modules to allow for students to do some of their modules at one of the other universities of the participating HEIs. To ensure best results from the E.U. sustainability agenda the programme will partner with rail-/and logistics-focused companies and institutions. This way, students will be moved away from specialized academic training towards new computer systems, research-driven solutions and real-life problems, which has a positive effect on driving economic progress in society at large.

[60] RiFLE Project web site, 2011, http://www.rifle-project.eu/ , accessed on February, 13, 2011

6 Recommendations and Strategies for Enhancing Rail Higher Education

The TUNRail project has provided the first opportunity for the U.S. and E.U. to benchmark the current state of rail higher education and its demand for the two regions. Additionally, TUNRail has also attempted to identify differences and synergies between the regions. It was soon recognized that pure benchmarking and data collection process is an extensive effort, as past efforts have been fragmented or absent. The identification of synergies was also challenging, as the history and structure (even terminology) of rail transportation systems differ significantly in the U.S. and E.U. The project included a survey of the railroad industry to determine its needs and compare those needs against existing programs. However, responses to such questions can be influenced by the lack of knowledge of railway higher education programs and their potential benefits, especially in the U.S. where rail higher education and programs have been absent for several decades.

Although railway higher education involves study of formal sciences, the railroad industry has greater need for practical knowledge than for academic knowledge. However the research for the TUNRail project indicates that practical knowledge founded upon a comprehensive rail higher education program has significant value. In order to provide the greatest benefit to the railroad industry, a comprehensive rail higher education program should transcend the boundary between academic and practical knowledge. Universities that provide railway operations laboratories and other practical applications of academic studies provide the connection between academic and practical knowledge and technologies that can provide the industry with graduates who are better prepared to begin immediate contributions toward the industry's success upon employment.

The TUNRail project has concentrated upon higher education in the engineering field; however, these subjects can add value to business management programs that involve railways and vice versa. Railways have natural constraints that pose unique business management problems. A fundamental knowledge of railway engineering and operations can make an important contribution to business management programs as well as engineering programs.

The following sections provide recommendations and strategies for universities and rail industry to improve the relevance of rail higher education to meet the current demands. The objective was to develop recommendations that were supported by the collected data and highlight some of the advantages and challenges / disadvantages of activities in each main category. As the inadequacy of current data became evident, some of the recommendations shifted from the implementation strategies to activities that improve the state of data collection in education and workforce development. Overall, recommendations are grouped under three categories and divided to several topics under each category. The categories and topics include:

- Data collection / research activities
    - Establish rail higher education data repository to store and disseminate data on available educational offerings in E.U. and U.S. and to support easier identification of synergies between universities.
    - Continue rail system comparisons between E.U. and U.S. with emphasis on developing standard set of metrics for both sides of Atlantic.
    - Initiate transatlantic research effort to identify areas of development with high priority for both E.U. and U.S. and investigate opportunities for collaborative research in these areas.
- Education and technology development
    - Establish an internet based knowledge database and related web portal to collect rail-related knowledge from university teachers from different parts of the world. Create technical content independent of national rules and principles to allow its better use for international education.
    - Establish more hands-on rail laboratories, either physical or virtual and make them available for students from other locations through web technologies. Use of other types of education that takes advantage of technology, such as computer games and simulations should also be expanded.
    - Expand course content beyond civil engineering and transportation.
    - Emphasize the importance of non-technical skills recognized important for global engineers in the education process. Identify opportunities to include (require) these skills to the learning process.

- University / industry and transatlantic collaboration
    - Develop strategies (or roadmaps) for industry, how to develop university / industry collaboration
    - Develop joint international activities (preferably in collaboration with industry) that allow increased interaction between the E.U. and the U.S. students.
    - Take steps to redevelop the U.S. academic infrastructure in rail higher education. Investigate opportunities for faculty visits by the E.U. professors to assist in the process.
    - Consider railway education through research, such as joint MS or PhD programs that include mandatory visits by candidates in the other side of Atlantic. Encourage the development of collaborative transatlantic programs in rail transportation, such as MIT / IST program

6.1 Data collection / research activities

Establish rail higher education data repository to store and disseminate data on available educational offerings in E.U. and U.S. and to support easier identification of synergies between universities. During the research it became evident that data on rail higher education is not readily available in E.U. and U.S. The lack of consistent data hinders the establishment of collaborative arrangements and makes it more difficult to compare and benchmark their activities with peer institutions. Consortia of institutions of higher education could establish a standardized data repository where universities could post their offerings, both for peer exchange and for students to investigate alternative education opportunities.

Continue rail system comparisons between E.U. and U.S. with emphasis on developing standard set of metrics for both sides of Atlantic. Comparing E.U. and U.S. rail systems is complicated. This can be expected, as systems have developed and operate in very different matter. However, it is also evident that the similarities are growing and a common set of metrics would be very useful to compare the performances of the systems and to identify potential synergies for collaborative activities.

Initiate transatlantic research effort to identify areas of development with high priority for both E.U. and U.S. and investigate opportunities for collaborative research in these areas. Over twenty percent of industry survey respondents identified their company as a "world-wide" organization. At the same time, industry agreed almost unanimously that transatlantic collaboration would benefit the professional rail field. As more companies function in both sides of Atlantic and as system synergies continue to develop the environment is becoming ripe for transatlantic research collaboration in areas that are considered a high priority for both sides.

Table 6.1 – Key Advantages, Challenges and Disadvantages

Key Advantages	***Challenges / Disadvantages***
• Proper and readily accessible data increases understanding of the systems, allows for benchmarking and facilitates identification of potential institutions for collaboration.	• Obtaining funding for data collection and updates is challenging, so such systems often rely on voluntary efforts. In addition, there is often reluctance to release certain data.
• As rail systems continue to develop, standard metrics provide "competitive environment" to validate system performances and to identify areas for improvements.	• Measuring systems with common parameters requires agreement between stakeholders which may face cultural and other challenges.
• Collaborative research allows taking advantage of the expertise and experiences in both sides of Atlantic and provides potential level of investment through economics of scale.	• Obtaining research funding that allows financial transactions or expenditures across Atlantic have been difficult. Alternatives where each party funds activities within their borders could be used to alleviate the challenge.

6.2 Education and technology development

Establish an internet based knowledge database and related web portal to collect rail-related knowledge from university teachers from different parts of the world. Create technical content independent of national rules and principles to allow its better use for international education. To date, the use of internet beyond national borders in rail higher education has been limited and majority of education concentrated heavily to each specific nation. One of the first steps to start the expansion and shift toward more global education could be a development of internet based knowledge database where institutions of higher education could store and disseminate data from different parts of the world. The first emphasis should be on content that is independent of national rules and principles. The knowledge database could be parallel and linked with the data collection effort and made accessible to all institutions involved in the field.

Establish more hands-on rail laboratories, either physical or virtual and make them available for students from other locations through web technologies. Use of other types of education that takes advantage of technology, such as computer games and simulations should also be expanded. The innovative technology research revealed extensive rail operational laboratories, especially in Germany. There laboratories are already used collaboratively by the German universities, but similar approaches would be beneficial beyond national borders. Today's students thrive with hands-on education, so more opportunities should be developed for such activities. The research also revealed that rail higher education hasn't yet taken advantage of educational technologies in larger scale. To address this, some laboratories could be virtual in nature to facilitate access that is unrestricted by physical location. Other potential approaches to take advantage of latest technologies and to meet the demands by today's students would be to take advantage of games in education.

Expand course content beyond civil engineering and transportation. The surveys and related competence gap analysis revealed that today's rail higher education is mainly limited to civil engineering and transportation domains while some of the topics with highest importance may be outside these areas. In addition, it was recognized that rail system requires uniquely multi-disciplinary understanding of the system components. Rail higher education should be expanded to other engineering areas, such as mechanical and electrical engineering, but also beyond engineering. For example, environmental aspects were considered one of the highest priorities by the industry. As number of students to such specialized courses may be limited, collaborative arrangements between institutions should be investigated as part of the implementation.

Emphasize the importance of non-technical skills recognized important for global engineers in the education process. Identify opportunities to include (require) these skills to the learning

process. Skills and personal characteristics beyond technical expertise were ranked high by industry experts. Even though rail specific classes that enhance skills beyond the field may not take place, students should be encouraged / required to obtain some of the key skills, such as leadership and communication from parallel studies. This could be facilitated through degree or certificate requirements that go beyond technical aspects. Introductions of internships and co-ops can also facilitate the development of leadership and other non-technical skills.

Table 6.2 – Key Advantages, and Challenges and Disadvantages

Key Advantages	***Challenges / Disadvantages***
• Internet based knowledge database allows the most efficient information exchange and easy access for extensive number of players.	• Just like with data collection, securing funding to develop knowledge database is challenging. International approach adds yet another layer of complexity with different languages, etc.
• Operational laboratories, games and other technology supported hands-on activities reflect the preferences of today's students, so they can be expected to improve the efficiency of education.	• The number of students in railway field will always be limited by the size of market. Development of elaborate laboratories may not be justified, based on annual number of students. Collaborative use of facilities with innovative funding schemes might alleviate some concerns.
• Expanding rail higher education to other supporting fields and encouraging education on skills beyond technical aspects will improve the preparedness of graduates to enter the industry. The area offers large amount of opportunities for collaboration.	• Game development requires extensive resources and may be hard to justify based on the size of market. It is also challenging to make games to sufficiently reflect reality and meet the learning outcomes.
• Internships / co-ops have been recognized to be one of the best ways to introduce students and industry companies to each other. They are low risk investments with potentially high rewards.	• Expanding required education beyond rail specific courses may be difficult to enforce due to limited authority by the rail faculty. It also requires coordination with other institutional entities.

6.3 *University / industry and transatlantic collaboration*

Develop strategies (or roadmaps) for industry, how to develop university / industry collaboration. The industry survey revealed that greatest obstacle for university / industry agreements is the perceived time commitment required for such activities. There should be an effort to understand the obstacles better and to develop guidelines, or roadmaps, to assist universities and industry to take steps that minimize the time commitments.

Develop joint international activities (preferably in collaboration with industry) that allow increased interaction between the E.U. and the U.S. students. Development of transatlantic activities is challenging for several reasons, not the least for the differences in academic schedules. However, the research on innovative and global educational approaches that some activities, such as web lectures, can be introduced with minimal effort. Other approaches for expanding E.U. / U.S. educational interaction include short-term summer schools and programs. These alternatives could have for various durations, ranging from a week to a full month or beyond and they could either run parallel for both E.U. and U.S. students (all students at same location), or at different times and locations with follow-up sessions that all students would participate on. They offer great potential to increase the global orientation of education and transatlantic collaboration. As the industry companies continue to expand their reach over Atlantic, opportunities for international internships should be looked into in larger scale. This can be facilitated by academia on both sides.

Take steps to redevelop the U.S. academic infrastructure in rail higher education. Investigate opportunities for faculty visits by the E.U. professors to assist in the process. The research indicated that the current extent of rail higher education is significantly larger in E.U. than in U.S. The industry also indicated that the current level of education is the U.S. was insufficient. The academic infrastructure in the U.S. requires rebuilding before it can provide the level of education needed by the expanding industry. Since the infrastructure has been absent for extended time, it would be opportune time to compliment the limited U.S. resources with European academic expertise in the rebuilding process.

Consider railway education through research, such as joint MS or PhD programs that include mandatory visits by candidates in the other side of Atlantic. Encourage the development of collaborative transatlantic programs in rail transportation, such as MIT / IST program. While the industry in the U.S. places high emphasis on the education through bachelor level programs, E.U. has much higher level of collaboration at MS and PhD level, partially due to closer research collaboration between academia and industry. As systems develop, it can be expected that U.S. will be investigating increasing investments for rail research. MS and PhD level education provides more flexibility to international collaboration due to less stringent course requirements and emphasis on research besides education. Therefore, collaboration at MS and PhD with a requirement for transatlantic activity would be less complicated to implement. MIT / IST joint MS program is a great example of such collaboration and additional programs with similar objectives should be considered in the future.

Table 6.3 - Key Advantages, and Challenges and Disadvantages

Key Advantages	***Challenges / Disadvantages***
• Roadmaps and other templates, or procedural documents may reduce anxiety by industry companies to collaborate with academia. If well monitored, they also allow continuous development of the relationships and reduce the time needed for individual agreements.	• Current level of annual research funding in the U.S. is unlikely to be sufficient to support greatly expanded academic infrastructure.
• Transatlantic activities (virtual or physical) allow direct interaction between students. If taught collaboratively, they also encourage	• Semesters begin and end at different time in Europe and U.S. In addition, many

interaction between faculties and provide opportunities to cover topics from both sides of Atlantic.	students want to work in the industry during summer periods.
• Increased academic infrastructure in the U.S. balances the system and provides needed resources for establishing transatlantic collaboration.	• Current transportation funding in the U.S. is limited and increase of rail expertise in the academia may be considered a low priority.
• International graduate studies and research offer great potential to advance the current state of technology and to provide new technical experts to the field. They typically require collaboration between faculties and students.	• Cost of exchanging students for joint MS may be prohibitive without dedicated funding source and international activities are prohibited by some several research grants. Lack of faculty expertise in rail might also become a challenge for E.U. students' research activities in the U.S.

Appendices

A-1: United States Universities with Rail Courses (separate Excel file)

A-2: United States University Rail Courses (separate Excel file)

B-1: United States Universities with Rail Courses (separate Excel file)

B-2: United States Universities with Rail Courses (separate Excel file)

C: On-line Industry Survey Questions

Appendix C: On-line Industry Survey Questions

Survey ID #34137

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This survey is conducted by TUNRail project, funded through EU-US Atlantis Program. The objective of the project is to establish closer collaboration between railway higher education in the US and EU, by increasing transparency, identifying similarities and differences between railway systems and educational programs, and by providing a solid foundation for more extensive cooperation and for the establishment of new programs on both sides of the Atlantic ocean. More information on the project is available on the TUNRail website: http://www.tunrail.info Survey has two parts. Part 1 is targeted to all professionals involved in the railway industry who have interest in improving higher education within the field and takes only 2-4 minutes to complete. Part 2 takes 10-15 minutes to complete and is targeted to those professionals who are involved in recruitment, technical training or other development activities, especially with university graduates. It attempts to collect information on quantitative and qualitative demands for university graduates in the rail industry and input on university education topics and industry-university relationships.

1. Gender:

[multiple choice; select one]

1. Male
2. Female

2. Name of Company/Organization/Institution:

[open response]

[____]

3. Type of Company/Organization/Institution (select the one that best describes your organization):

[multiple choice; select one]

1. Small and Medium Enterprise
2. Large Enterprise
3. Class 1 Railroad
4. Engineering Consultant
5. Contractor
6. Supplier/Manufacturer
7. Transit Agency or Authority
8. Other Please Specify [________________________________]

4. Geographical scope of company?

[multiple choice; select one]

1. EU
2. North America
3. Worldwide
4. Other: Please Specify [________________________________]

5. Position in the Company/Organization/Institution:

[open response]

[____]

6. Department (if applicable):

[open response]

[____]

7. Country:

[open response]

[____]

8. What is your educational background?

[multiple choice; select one (required)]

1. High School / Vocational School
2. Associate Degree
3. BS
4. MS
5. Ph. D

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9. Graduation Major:

[multiple choice; select one]

1. Business
2. Economics
3. Mechanical Engineering
4. Electrical Engineering
5. Civil Engineering
6. Construction Management
7. Other: Please Specify [____]

10. Did you have any exposure to railway prior to attending a university?

[multiple choice; select one]

1. Yes (please explain) [____________________]
2. No

11. Did you have any exposure to railway education while in a university?

[multiple choice; select one (required)]

1. Yes
2. No

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12. What type of exposure did you experience?

[multiple choice; select all that apply]

1. Professional Courses
2. A subject in a BSc Program
3. A BSc Program
4. A subject in a MSc Program
5. A MSc Program
6. Full Semester University Courses
7. Short Post-graduate Courses
8. Distance Learning
9. eLearning
10. Blended Learning

13. Did that exposure play a role in your career decision?

[multiple choice; select one]

1. Major
2. Minor
3. None

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14. What was your year of graduation?

[open response]

[__________]

15. How long have you been employed in rail industry?

[open response]

In years [__________]

16. In your country, are you aware of railway education provided by universities?
[multiple choice; select one (required)]

1. Yes
2. No

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17. Please indicate the type of education.
[multiple choice; select all that apply]

1. Professional Courses
2. A subject in a BSc Program
3. ABSc Program
4. A subject in a MSc Program
5. A MSc Program
6. Full semester university courses
7. Distance Learning
8. eLearning
9. Blended Learning

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18. Do you think that employees with university education in the following areas would add value to your organization?
[multiple choice; select all that apply]

1. Rail Operations and Management

2. Rail Economics
3. Rolling Stock
4. Signal and Communications
5. Rail Policy and Strategy
6. Rail Marketing
7. Urban Planning and Mobility
8. Rail Infrastructure Engineering
9. Transportation and Logistics
10. Rail Safety and Security

19. If you are a rail-focused organization, does your organization collaborate with institutions that provide Rail Higher Education?

[multiple choice; select one (required)]

1. Yes
2. No

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20. Please name them:

[open response]

[______________________________]

[______________________________]

[______________________________]

[______________________________]

[______________________________]

[______________________________]

[______________________________]

[______________________________]

[______________________________]

[______________________________]

21. What kind of collaboration do you have?

[multiple choice; select all that apply]

1. Research Projects
2. Guest Lectures
3. Internship / Co-op Programs
4. Educational Collaborations
5. Financial Sponsorship
6. Other: please specify [____]

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22. Do you believe that increased collaboration between universities and industry would benefit railroads in:

[multiple choice; select all that apply]

1. Recruitment
2. Retention of Employees
3. Industry Research/Development
4. Increasing Industry Visibility
5. Increasing Efficiency and Productivity
6. Increasing Safety and Security
7. Profit
8. Prosperity and Reputation
9. Innovation and Creativity

23. Do You Believe Trans-Atlantic collaboration would benefit the railroad industry?

[multiple choice; select one]

1. Yes
2. No

24. Can you explain why or why not?

[open response]

[____]
[____]
[____]
[____]
[____]
[____]
[____]
[____]
[____]
[____]

25. Thank you for participating in Part 1 of the survey. The second part will take 10-15 minutes to complete and is targeted to the rail industry professionals involved in recruitment, training and supervising young professionals. It will attempt to collect information on quantitative and qualitative demands for university graduates in the rail industry and input on university education topics and industry-university relationships. Do you wish to continue?
[multiple choice; select one (required)]

1. Yes
2. No

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26. Please provide any other comments that you may have.
[open response]

[____]
[____]
[____]

[____]
[____]
[____]
[____]
[____]
[____]
[____]

27. If you would be interested in receiving information on survey results on the TUNRail project, please provide your name and e-mail at this time.
[open response]

Name [______________________________________]

e-mail [______________________________________]

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28. Please indicate (in proportion) the education level of your organization's employees, only considering the employees working mainly in the railway activities. Provide the total number of employees that fit the criteria (if you don't have actual numbers, please provide your best estimate).
[open response]

Total # of employees in company? [__________]

Total # of employees in positions related to rail activities? [__________]

29. Level of Education: (Number or Percentage (%) of Employees)
[open response]

Associate/Technician (Secondary school with higher education course not exceeding 2 years)	[__________]
Undergraduate - Bachelor Course (3-5 Years of Higher Education)	[__________]
Post Graduate - Master Course (5-7 years of Higher Education)	[__________]
Ph. D or Multiple Degrees - Doctorate or higher education exceeding 7 years	[__________]

30. In the past 1-5 years, has the number of employees involved in rail activities in your company/department:
[multiple choice; select one]

1. Increased
2. Decreased
3. Stayed the Same

31. How many university graduates do you expect to hire to rail related positions within the next:
[open response]

1 year [__________]

3 years [__________]

5 years [__________]

32. Overall, do you expect the number of rail related positions within the next three years to:
[multiple choice; select one]

1. Increase
2. Decrease
3. Stay the Same

33. By what percent (or number) and why?
[open response]

[____]
[____]
[____]
[____]
[____]
[____]
[____]
[____]
[____]
[____]

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Please consider the following list of competences in the railway domain. For every competence, can you please rate its relevance for your organization's activities in the railway sector? Please rate on a scale from 1-5 (1-Not Relevant, 2-Somewhat Relevant, 3-Relevant, 4-Very Relevant, 5-Absolutely Essential, or N/A if Not Applicable)

34. Rolling Stock and Traction:
[matrix; select one in each row]

	Not Relevant	Somewhat Relevant	Relevant	Very Relevant	Absolutely Essential	Not Applicable
Car Body and Construction	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

Bogies, Running Gear and Braking	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Interiors, Auxiliaries, HVAC	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Traction and Power Supply	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Other: Please Specify Below	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

35.
[open response]

[______________________]

36. Systems Engineering:
[matrix; select one in each row]

	Not Relevant	Somewhat Relevant	Relevant	Very Relevant	Absolutely Essential	Not Applicable
Interoperability	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
System Integration and Engineering Interfaces	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Testing Verification and Qualification	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Other: Please Specify Below	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

37.
[open response]

[____________________]

38. Civil Engineering and Infrastructures:
[matrix; select one in each row]

	Not Relevant	Somewhat Relevant	Relevant	Very Relevant	Absolutely Essential	Not Applicable
Tracks, Switches and Crossings	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Structures (Bridges, Tunnels, Etc)	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Stations	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Other: Please Specify Below	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

39.
[open response]

[____________________]

40. Control Systems:
[matrix; select one in each row]

	Not Relevant	Somewhat Relevant	Relevant	Very Relevant	Absolutely Essential	Not Applicable

Signaling, Control Command and Interlocking	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Train Control, Positioning and Communications	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Electromagnetic Compatibility	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Other: Please Specify Below	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

41.
[open response]

[____________________]

42. Operations:
[matrix; select one in each row]

	Not Relevant	Somewhat Relevant	Relevant	Very Relevant	Absolutely Essential	Not Applicable
Passenger	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Freight	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Technical and Commercial Exploitation	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Resources	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

Management						
Intermodality	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Other: Please Specify Below	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

43.
[open response]

[____________________]

44. Environment:
[matrix; select one in each row]

	Not Relevant	Somewhat Relevant	Relevant	Very Relevant	Absolutely Essential	Not Applicable
Noise and Vibrations	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Air Pollution and Energy Savings	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Sustainable Development, Recycling and Waste Management	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Other: Please Specify	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

45.
[open response]

[______________________]

46. Economics, Business, Regulations:
[matrix; select one in each row]

	Not Relevant	Somewhat Relevant	Relevant	Very Relevant	Absolutely Essential	Not Applicable
Economics	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Regulations	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Business Management	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Cost, Asset Management, Life Cycle Costs	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Marketing Management	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Public Service, Social and Political Issues	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Other: Please Specify Below	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

47.
[open response]

[______________________]

48. Multidisciplinary Issues:
[matrix; select one in each row]

	Not Relevant	Somewhat Relevant	Relevant	Very Relevant	Absolutely Essential	Not Applicable
Security and Safety	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Risk analysis and Failure Mode Analysis	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Human Factors	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Reliability, Availability, Maintenance and Safety (RAMS)	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Quality Management	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Computer Technology and Networking	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Light Rail, Tram and Tram-train Systems	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Other: Please Specify Below	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

49.
[open response]

[______________________]

Please rate the following list of criteria in terms of relevance for the success of undergraduate employees in working in the railway activities. (Scale 1-5; 1-Not Relevant, 2-Somewhat Relevant, 3-Relevant, 4-Very Relevant, 5-Absolutely Essential, or N/A if Not Applicable)

50. Education:
[matrix; select one in each row]

	Not Relevant	Somewhat Relevant	Relevant	Very Relevant	Absolutely Essential	Not Applicable
University Grade	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
History of Leadership (e.g.: Academic Activities, Voluntary Working)	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
University Course(s) in an area close to railway domain	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
University Degree in Railway Program (Bachelor or Masters)	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Previous experience in working (e.g.: Internship)	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

Previous experience in railway related work (e.g.: Internship)	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Other: Please Specify Below	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

51.
[open response]

[____________________]

52. Personal Profile:
[matrix; select one in each row]

	Not Relevant	Somewhat Relevant	Relevant	Very Relevant	Absolutely Essential	Not Applicable
Demonstrated interest in railways	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Mobility and willingness to relocate	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Willingness to work outdoors	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Willingness to work irregular schedules and long days	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Ability to work in a fast pace environment	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

Ability to work under stress and time constraints	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Other: Please Specify Below	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

53.
[open response]

[____________________]

54. Skills:
[matrix; select one in each row]

	Not Relevant	Somewhat Relevant	Relevant	Very Relevant	Absolutely Essential	Not Applicable
Problem Solving	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Analytical and Technical	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Theoretical	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Oral and Written Communications	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Leadership	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Ability to work in multidisciplinary teams	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

Other: Please Specify Below	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

55.
[open response]

[_____________________]

Please indicate the most important background degrees that your company will be recruiting for railway related positions. Please rank each background by relevance. (1-Not Relevant, 2-Somewhat Relevant, 3-Relevant, 4-Very Relevant, 5-Absolutely Essential, or N/A if Not Applicable)

56. Engineering:
[matrix; select one in each row]

	Not Relevant	Somewhat Relevant	Relevant	Very Relevant	Absolutely Essential	Not Applicable
Aerospace	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Automotive	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Chemical	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Civil	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Communication	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Computer/Software	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Electrical/Electronics	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Industrial	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

Materials	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Mechanical	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Railways	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
System	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Other: Please Specify Below	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

57.
[open response]

[____________________]

58. Other disciplines
[matrix; select one in each row]

	Not Relevant	Somewhat Relevant	Relevant	Very Relevant	Absolutely Essential	Not Applicable
Economics and Law	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Social Science	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Marketing and International Relations	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Political Sciences	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Other: Please Specify Below	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

59.

[open response]

[____________________]

60. Comments: Can you please detail the main areas of under performance of the recently recruited employees with undergraduate level?

[open response]

[____]

[____]

[____]

[____]

[____]

[____]

[____]

[____]

[____]

[____]

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61. Does your organization have relationships or special agreement with Universities (undergraduate courses) in the field of railways?

[multiple choice; select one]

1. Yes
2. No
3. I don't know

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62. Can you please name the Universities?

[open response]

[____]

63. Can you please indicate the purpose of the agreement:

[multiple choice; select all that apply]

1. Providing Educational Material
2. Providing Guest Lectures
3. Cooperating in Research Projects
4. Funding Research
5. Funding Educational Programs (such as student clubs or enterprises)
6. Funding Faculty or Staff Positions
7. Providing Endowments
8. Offering Scholarships
9. Working with Career Centers and Being at Job Fairs
10. Organizing University Events to Promote Railroads
11. Other Ways to Increase On-Campus Visibility
12. Other: Please Specify [_____________________]

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64. Can you please indicate the main reasons:

[multiple choice; select all that apply]

1. There is not apparent benefit in engaging deeper university relations
2. There was no interest by universities when we contacted them
3. Time commitment for such activities is to high

4. Don't know who to contact at the universities
5. Other, please specify [____________________]

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65. Would you consider that universities' current courses (curricula) are adequate or inadequate for addressing the key competences you have rated above?
[multiple choice; select one]

1. Adequate
2. Inadequate
3. I Don't Know

66. Comment: Can you please indicate other areas of expertise or competence that universities should provide to undergraduate students?
[open response]

[____]
[____]
[____]
[____]
[____]
[____]
[____]
[____]
[____]
[____]

67. What types of university education would you consider most beneficial for graduates? (Please us a scale of 1-Not Necessary, 2-Somewhat Beneficial, 3-Beneficial, 4-Very Beneficial,

5-Extremely Beneficial, Not Applicable)

[matrix; select one in each row]

	Not Necessary	Somewhat Beneficial	Beneficial	Very Beneficial	Extremely Beneficial	Not Applicable
Introduction to Rail (5-10 lecture hours)	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Seminar or Certificate in Rail Topics	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Semester Long Course in Railroad Engineering (3 Credits)	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
On-Line or Distance Education Course	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Minor in Railroad Engineering (12 Credits)	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Rail Entrepreneurial Programs (Student Companies)	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Opportunities for Funded Student Research in Rail Topics	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Graduate Studies in Railroad Engineering	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

(45 Credits)						
Co-ops and/or Internships	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Other: Please Specify Below	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

68.
[open response]

[____________________]

69. Would increased university participation be beneficial in following topics? (1-Not Necessary, 2-Somewhat Beneficial, 3-Beneficial, 4-Very Beneficial, 5-Absolutely Essential, Not Applicable)
[matrix; select one in each row]

	Not Necessary	Somewhat Beneficial	Beneficial	Very Beneficial	Absolutely Essential	Not Applicable
Recruitment	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Providing Specialized Education	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Promoting Rail Transportation	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Increasing Customer Satisfaction	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Boosting Rail Productivity and	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

Competitiveness						
Maximizing Rail Safety and Security	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Maximizing Railway System's Capacity	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Encouraging Modal Shift and Intermodal Services	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Promoting rail Industry and Culture	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Providing Basic Railway Education (Introductory Lectures, Seminars or a Single Course)	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Undertaking Railway Research	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Maximizing the Benefits of the Railway to the Environment	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Maximizing Rail's Energy Efficiency	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

70. The TUNRail team would be interested in making a limited number of follow-up interviews with key experts. If you were willing to participate in 20 minute follow-up phone interview, please provide your name, email address and phone number below.
[open response]

Name: [______________________________]

Email Address: [____]

Phone Number: [____________________]

71. If you have any other comments or questions, please provide them below.
[open response]

[____]
[____]
[____]
[____]
[____]
[____]
[____]
[____]
[____]
[____]

Final Message

Thank you for participating in the TUNRail survey. We appreciate your input in developing 21st century railway higher education. If you want more information on TUNRail project, please visit our web site at www.tunrail.info or contact Pasi Lautala at ptlautal@mtu.edu

Yours Sincerely,

TUNRail Team