BEFORE THE
UNITED STATES HOUSE OF REPRESENTATIVES

COMMITTEE ON
SCIENCE, SPACE AND TECHNOLOGY

SUBCOMMITTEE ON RESEARCH AND TECHNOLOGY

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18 June 2014
Washington, DC

Chairman Bucshon, Ranking Member Lipinski, and members of the Subcommittee, thank you for the opportunity to participate in this important discussion today. My name is Chris Barkan and I am a Professor in the Department of Civil and Environmental Engineering at the University of Illinois at Urbana-Champaign (UIUC) where I also serve as Executive Director of the Rail Transportation and Engineering Center at the University and Director of the National University Rail (NURail) Center, which UIUC leads, and includes the University of Illinois at Chicago, University of Kentucky, University of Tennessee – Knoxville, Massachusetts Institute of Technology, Michigan Technological University and Rose-Hulman Institute of Technology and is managed by the U.S. DOT Office of the Assistant Secretary for Research and Technology. Prior to my position with the university, I worked at the Association of American Railroads (AAR) in Washington, DC, where I managed and conducted research on behalf of the rail industry to improve the environmental and safety performance of railroads. Rail research has been the principal focus of my entire professional career of 26 years with the AAR and UIUC.

Let me state at the outset, that the opinions I express are my own and do not necessarily represent those of the University of Illinois.

I was invited to participate today to address the following three topics:

1) What is the future of U.S. rail transportation? What will be the role of R&D in achieving this vision for the future?
2) What are some technical and policy challenges in railroad R&D? How will this research and technology improve passenger safety, increase economic output, and lower environmental effects? How soon will this research be widely implemented in the U.S.?
3) Please describe some workforce development initiatives at your Center.

Although I will primarily be discussing rail, it is critical to understand that rail is part of an integrated, multi-modal transportation system and the overarching theme of my remarks should be viewed in this context.

The economic competitiveness of the United States in the global marketplace is highly dependent on safe, reliable and efficient movement of people and goods over an integrated, balanced, multi-modal transportation network. The U.S. achieved its position of international economic leadership in the 20th Century in no small part because it had developed the best transportation system in the world; first its railways, and later its highways and airways, supplemented where appropriate and feasible by inland and coastal waterways and pipelines.

Each of these modes has unique attributes that make it best suited for a particular niche within the system. Although transportation discussions sometimes devolve to pitting one mode against another, that is really not the appropriate way to consider the matter. If we use one mode where another is better suited, then we are sub-optimizing because we are using more energy, land, labor or some other resource less efficiently than would otherwise be the case. In the competitive, global marketplace that has emerged over the past several decades, sub-optimizing our use of transportation puts us at a serious disadvantage from the outset.

Despite significant inefficiencies, our 20th Century transportation system succeeded because of abundant U.S. resources and limited international competition. However, neither of those conditions exists today, and certainly will not in the future. Resources are becoming scarcer, the demand for them is increasing, and there are a number of vigorous, foreign economies competing with our own. Furthermore, we now understand that wasteful use of resources, particularly, energy, is not sustainable and has long-term impacts that we must be mindful of. This is particularly true of petroleum. Transportation is the largest consumer of petroleum-derived energy in the U.S. and even with the influx of newly tapped, domestic sources, the amount is finite and its consumption has implications for air quality.

In short, business as usual – including how we transport goods and people – will not suffice in the 21st Century. We need new solutions to align our transportation system to this new era and research is all about finding those solutions, while at the same time developing a new generation of transportation professionals who will plan, design, build, maintain and operate the transportation systems of the future.

1a) What is the future of U.S. rail transportation?

The resurgence of the U.S. freight railroad system over the past three decades is one of the stunning transportation success stories of the latter 20th and early 21st centuries. As a result, the North American freight rail system is considered among the best in the world. U.S. railroads transport 43% of the intercity freight ton-miles, the largest share by a considerable margin (trucks are second with 31%). While the nation struggles with the problem of funding the necessary renewal of its highway system, the private sector freight railroads are investing billions renewing, improving and expanding their physical plant, almost entirely without taxpayer support. As already mentioned, railroads' efficiency provides the U.S. with substantial economic, energy, environmental and safety benefits that are crucial to our future as a successful, globally competitive nation.

With regard to passengers, increasingly congested highway and air transport systems, concerns about energy scarcity and cost, and the need for safe, environmentally sustainable public mobility and urban livability favor investment in modern and efficient urban, regional and intercity passenger rail systems. Numerous cities are developing or expanding their rail transport systems and intercity passenger travel continues to increase, despite only limited improvements. Nevertheless, our passenger rail system is on a much less secure financial footing than the freight railroads because of the need for public sector support.

Railroads' niche in the transportation system is that they uniquely combine high speed and energy efficiency with the ability to move large quantities of heavy freight or large numbers of passengers at relatively low cost. However, they can only achieve this with substantial investment in a capital-intensive physical plant. Railroads excel when there are large economies of scale, i.e. when there are large quantities of freight that need to be moved long distances, or large numbers of people moving along the same route. Under these conditions, investment in the physical plant needed can be justified because the cost of the investment is shared by large numbers of users, thereby making the cost to each individual quite low. It is generally inefficient to use other modes when the criteria for rail are met, and conversely, it is generally inefficient to use rail if they are not.

The physical characteristics inherent to rail transport are the fundamental reason for its tremendous efficiency and they also drive the need for sophisticated infrastructure. These lead

directly to a suite of characteristics unique to rail transport that contribute to its ability to provide safe, economical, energy efficient, environmentally sustainable transportation. The underlying physics of rail transport mean that no other mode can offer its unique combination of characteristics, hence its significant role as part of a multi-modal system.

The factors driving these trends favoring the efficiencies offered by freight and passenger rail will only increase, so its integral importance as part of a balanced, multi-modal freight and passenger transportation system is destined to further increase as well. Simply put, the U.S. must take optimal advantage of all of its transport modes in a balanced manner, and rail has an increasingly vital role to play.

1b) What will be the role of R&D in achieving this vision for the future?

Those unfamiliar with rail transport might be inclined to suggest that because of its maturity, there is little need for research. In fact, nothing could be further from the truth. Although the basic elements of modern rail transport have been around for nearly two centuries, both the technologies and the demands being placed on them are dramatically different than they were even a few decades ago. Railroads are under continuous pressure to advance by improving safety, efficiency, speed, capacity and performance, as well as adapting to new market demands and the availability of new technologies. The rapid growth in rail transport is placing intensive new demands on railroads, which requires R&D on a broad range of topics including all branches of engineering, information technology, computer science, analytics, operations research, planning and policy. Put another way, there is a virtuous circle by which railroad's ongoing quest for improved performance demands R&D solutions, which in turn creates new opportunities for rail.

2a) What are some technical and policy challenges in railroad R&D?

Perhaps the most important technical and policy challenge facing US railroads is how to continue to improve our economically healthy, self-sustaining freight rail system, while at the same time increasing its potential to provide high-quality, sustainable passenger rail transport.

Development of both incremental (passenger trains on track shared with freight trains) and very High-Speed Rail (HSR) lines (with right-of-way dedicated to high-speed passenger trains) in the U.S. poses a number of new challenges related to shared trackage, shared right of way, and shared corridor engineering, operation and policy. Despite more than 50 years of international experience planning, designing, building and operating high-speed passenger rail infrastructure and rolling stock elsewhere in the world, there are numerous questions unique to North America that need to be answered if advanced passenger rail technologies are to be successfully implemented.

Passenger rail transport has advanced to a complex set of integrated, advanced systems overseas. Meanwhile, a similar transformation has occurred on North American freight railroads.

U.S. railroads have developed sophisticated technologies that allow them to move enormous volumes of freight at very low cost, with the resultant benefit to manufacturers, consumers, and our economy in general. Most people outside the rail community do not realize that just as we look with envy at the high-speed passenger rail systems elsewhere in the world, they look at our highly efficient freight rail system with similar envy. That these two different types of rail system are not congruent is not a coincidence. It is because each system has been optimized for its respective mission: very high-speed passenger rail, or high efficiency freight rail. A major R&D challenge is developing new knowledge to continue advancing the state of the art of freight rail, while at the same time, understanding when, where and how we can safely and efficiently expand passenger train frequency and speed in a manner that does no harm to the freight rail franchise that we all benefit from. The research topics to address this range from pure engineering to pure policy, and we need to address the entire spectrum of challenges and opportunities. An important role of government should be to pursue policies that will encourage partnerships between potential passenger rail operators and the freight railroads so that both parties benefit.

Aside from the shared rail corridor challenges, another important policy concern affecting implementation of R&D is regulatory constraints that may inhibit adoption of new technologies. Many current safety regulations were written decades ago and some as long as a century ago. Although some of the safety concerns they are intended to address remain similar, the technology options to measure and monitor the condition of railroad infrastructure and rolling stock have advanced enormously. Advanced sensing, analysis and inspection technologies are being developed that can measure and monitor component condition in a reliable, repeatable manner. This information, integrated with proper use of the resultant data and management systems will enable further improvements in safety, efficiency and quality of rail service. Our regulations should be designed to encourage the development and implementation of such advances, rather than be a barrier to deployment.

Current regulations often do not account for, or even permit these technologies to be used to their full advantage, even though their use could improve safety. The regulatory structure should embrace and encourage development and implementation of such technologies, coupled with a modern, risk-based approach.

2b) How will this research and technology improve passenger safety, increase economic output, and lower environmental effects?

The Federal Railroad Administration (FRA) Office of Research, Development and Technology (RD&T) conducts research on a variety of topics related to infrastructure, rolling stock, signals and communication, and human factors with a unifying theme focused on safety, consistent with their mandate from Congress. The FRA also funds the Transportation Research Board Safety IDEA (Innovations Deserving Exploratory Analysis) Program, which sponsors research on rail safety and innovative technology topics. The TRB National Cooperative Rail

Research Program sponsors research on rail policy, planning, practice and efficiency. The Federal Transit Administration also has a research program that includes projects addressing certain aspects of rail safety, infrastructure condition and operating efficiency.

In the private sector, major railroads and suppliers conduct research on various topics addressing safety, infrastructure, rolling stock performance, efficiency, environmental impact, network planning and efficiency, and in addition, collaborate on an array of research topics through the Association of American Railroads research program, which is managed and conducted by the Transportation Technology Center, Inc. on behalf of AAR. In addition to its own research activities, the AAR program includes support for rail research at three U.S. universities known as AAR Affiliated Labs. UIUC has been one of these Affiliated Labs for over 30 years and this AAR support has been invaluable to development of our successful rail program, and continues to be a fundamental cornerstone. The Railway Supply Institute also cooperates with the AAR on an ongoing program of research specifically focused on improving the safety design of railway tank cars, intended to reduce the risk of transporting hazardous materials.

These organizations are engaged in, or sponsoring, research on a number of topics that will improve passenger and freight rail safety. There is less research directly addressing economic output, but a number of topics focused on safety, infrastructure condition, rolling stock reliability and improved energy efficiency indirectly address this. The principal research addressing reduction of environmental impacts is related to energy efficiency and locomotive emissions reduction.

The NURail Center is also addressing many of these questions through its research projects. In addition, we are taking a longer-term view by developing Strategic Development Plans (SDP), to address a broader suite of related topics in an coordinated manner and help us prioritize and focus our research and educational activities. These SDPs involve a several sub-themes ranging from technology and operations, to planning and policy as follows:

Integrated Railroad Track/Vehicle Interaction and Dynamics Modeling
Railroad Safety and Risk
Rail Network Capacity Analysis and Planning
Urban, Regional and High-Speed Passenger Rail Implementation
Multimodal Freight Transportation
Funding, Finance, Community and Economic Development

2c) How soon will this research be widely implemented in the U.S.?

The implementation of research results can range from weeks or months, to years or even decades, depending on the topic and the nature of the results. The principal constraints on implementation of new technologies are related to the rate that they can be developed and deployed, which are two separate processes. Development is related to completion of the

necessary R&D and deployment is related to whether the results are intended to change practices or will require new hardware. If the latter, the time and investment needed to develop manufacturing capacity, plus the time and financial resources required to install the technology will affect implementation rate.

Development is primarily constrained by the financial and human resources available to address problems. Quite simply, more funding and more people with knowledge and understanding of rail engineering and transport has a direct impact on the rate of development of new knowledge and solutions to problems. There is far less funding for rail research than other modes. There is little doubt that this constrains development of new solutions and it also undermines the ability to attract and educate faculty and their students in the principles of rail transport. I will return to this topic later.

The ability to implement these new technologies is affected by the regulatory environment described above and by the financial resources needed for deployment. I have already discussed the need for regulatory reform. With regard to funding, railroads are a highly capital intensive industry so every investment must be judged carefully on its ability to achieve its intended safety, operational or efficiency objective. The U.S. freight railroads are almost entirely owned and operated by the private sector. Since they were partially deregulated in 1980 these railroads have invested hundreds of billions of dollars upgrading their infrastructure and rolling stock with corresponding benefits in safety, efficiency, reduced environmental impact and reliability. As their financial health has continued to improve they are investing in even more new and advanced technologies that improve all aspects of their performance. I see no reason why this trend will not continue as long as railroads are permitted to operate in a manner that provides a reasonable rate of return that encourages capital investment.

The passenger side is more challenging, Amtrak suffers from perennial uncertainty in its funding and many commuter rail agencies struggle to find the capital resources needed for them to maintain their existing physical plant in a state of good repair, never mind implement new technologies. This is not to say that they are not advancing but the pace of this could be considerably accelerated if more funding were available.

3) Please describe some workforce development initiatives at your Center.

In the latter half of the 20th Century, colleges and universities in the U.S. shifted their transportation education programs to focus on educating young engineers and transportation practitioners in highway and air transport. As a consequence, we developed an extensive, highly skilled workforce with world-class expertise in these fields. However, this was accomplished at the expense of education in other modes, including rail. A colleague and I estimated that by the early 2000s, there was approximately 100 times more funding for highway education and research programs in the U.S. than for rail. The results of such an imbalance are predictable, we

have far fewer professors and students with sufficient education and understanding of the fundamental principles of railway engineering and transport than we need, especially given the renaissance in rail that is now underway.

Academic rail programs might have disappeared entirely, were it not for the AAR Affiliated Lab program, which for more than two decades was the only program in the U.S. whose mission specifically included support for academic rail research and encouraged rail education at the three affiliated universities. This led to engagement and development of faculty expertise in rail at these universities. Faculty serve as magnets to attract, inspire and educate students in rail topics, thereby encouraging and preparing them for rail careers. Despite the limited number of universities involved, a number of graduates went on to positions in the rail industry. The situation began to improve in the late 2000s when FRA began to understand that they could support rail workforce development by funding rail research at colleges and universities thereby building upon the initial AAR success.

A major breakthrough occurred in 2011 when the US DOT Research and Innovative Technology Administration (RITA) reorganized its University Transportation Center (UTC) Program and issued a request for proposals encouraging a multi-modal perspective. This was a significant change for the UTC program, which had focused primarily on highway transport throughout its nearly 25-year history. In the resultant competition the University of Illinois at Urbana-Champaign led a consortium of seven colleges and universities that proposed formation of the National University Rail (NURail) Center. The NURail proposal was selected and for the first time in the program's history, there was a UTC whose principal focus was on rail transportation and engineering. The NURail Center selected Shared Rail Corridors as its principal theme because we recognized the topic's critical importance to freight and passenger railroads, and to both private and public sector rail organizations.

From its inception, railroad work force development has been a principal objective of the NURail Center and is an important element of the UTC program's mission in general. Work force development is important throughout the transportation sector, but it is a particularly important problem for railroads due to their aging work force. Some railroads have estimated that 50% of their employees will reach retirement age in the next five years, making the need to replace them acute.

Work force development activities in the NURail Center include education of students at all levels ranging from elementary school to doctoral students, and all levels in between. Our mission also includes educating professionals already in the work force through continuing education activities such as workshops, conferences, short courses and on-line education and NURail partners are engaged in all of these.

Attracting students and educating them in rail transportation includes a range of activities. An important traditional approach is to offer courses and a curriculum in rail transport topics for students. NURail has been quite active in this role addressing it in diverse and complimentary ways. For example, one of our parters, Rose Hulman Institute of Technology, is developing an introductory course in railroad engineering suitable for use by smaller engineering colleges. It will include elements of civil, mechanical and electrical engineering, thereby providing a general course introducing students to the topic. At the other end of the spectrum, at my school, the University of Illinois at Urbana-Champaign, we are expanding our existing four-course curriculum on freight rail transportation and engineering, and are also developing a new, three-course, specialized curriculum in high-speed rail planning, engineering and construction management. NURail partners are also developing specialized technical topics to be integrated into other areas of their academic curriculum. For example, the University of Kentucky is developing specialized modules on railway material science topics that will be incorporated into their materials engineering courses. At MIT their graduate curriculum presents rail transport as part of a complex socio-technical system, helping students understand how railroads interact with other elements of society and the economy, and their consequent impact on private and public sector policy.

In addition to activities on our campuses with traditional college-age students, NURail partners are also educating other age groups in various ways. For example at our sister campus, the University of Illinois at Chicago, they are developing a management training program for METRA, which is Chicago's regional commuter railroad. The University of Tennessee at Knoxville, offers short courses to short line and regional railroads to assist them developing more effective railroad track safety inspection practices. At Michigan Technological University, they host a Rail and Intermodal Transportation Summer Youth Program that attracts high-school age students from cities throughout the midwest, with a specific focus on inner city youth.

In addition there are a number of other ways that NURail is encouraging and supporting work force development. In addition to course work, graduate students conduct research on a broad range of rail-related topics. In addition to the advanced domain knowledge this provides them, their experience developing and managing an independent research project substantially enhances their organizational and problem-solving skills preparing them well for entry-level management positions in the rail industry. Those graduate students who are completing Ph.D.s may enter industry or rail research positions, or they may pursue academic careers where they will leverage their rail knowledge by teaching a new generation of rail students at other universities.

Another NURail workforce development activity is also about leveraging. NURail faculty members collaborate with the American Railway Engineering and Maintenance of Way Association (AREMA) and the American Society of Civil Engineers (ASCE) to conduct a "teach the teacher" event called the Railway Engineering Education Seminar (REES). Dozens of

professors from all over the nation gather for three days of intense classes, presentations and discussions by NURail faculty. NURail faculty provide these professors with teaching materials that they can incorporate into courses and curricula at their respective colleges and universities.

As already discussed, there are extensive opportunities for new, state-of-the-art freight and passenger rail technologies. 21st Century rail transportation requires increasingly sophisticated skills and expertise, but the U.S. lacks sufficient educational infrastructure to replenish the generation of rail professionals that are retiring every day. The NURail Center's educational and work force development activities are a beginning, but more is needed. Furthermore, it will take time to rebuild an academic "infrastructure" comparable to that of other modes, especially highway transport, yet this is essential to achieving the vision.

Congress and the transportation community understand the need for funding to renew, rebuild and expand our nation's transportation infrastructure. However, we need to be equally cognizant of the need to attract and educate the next generation of transportation professionals who will plan, design, build and operate this infrastructure. We must find the funds to rebuild our transportation system, and we must ensure that they are used as effectively as possible by taking advantage of the latest research and employing the best and brightest young minds. This is one reason why the UTC program is so important, not just to rail, but to the entire transportation enterprise.

UTCs are a critical element in our nation's ability to achieve this goal and should be reauthorized in full. The legislative language should clearly support a multi-modal focus and allow centers latitude to take full advantage of their strengths addressing the often inter-related U.S. DOT strategic goals. It should also allow for additional centers beyond the core program to be funded by other government agencies. Finally, competitive selection of centers helps ensure that UTC awards are based on merit. This takes best advantage of the human and institutional resources available to advance the quality of the U.S. transportation system. It encourages and supports development of a world class, modally balanced, transportation infrastructure and work force.

Transportation professionals agree that the U.S. (indeed any nation) needs a balanced transportation system that properly accounts for its particular combination of demands and takes advantage of the strengths that each mode has to offer. Achieving a balanced transportation system requires a balanced transportation education system. Federal and state DOTs invest heavily in education and research that supports highway transport, we need to expand investment in education in other modes, including rail so that we can rebuild the technical expertise needed for the rail workforce of the 21st century.