Industry/Academic Cooperation in Transportation: The Partnership of JR East and MIT

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Introduction

This article describes a program of joint research and education established between East Japan Railway Company (JR East) and the Massachusetts Institute of Technology (MIT).

At the outset, it is important to stress the partnership nature of the relationship between these two organizations. In many ways, MIT and JR East have different missions. JR East is an operating railroad company with responsibility for providing critical passenger transportation services in the most heavily populated region of Japan. MIT is an academic organization focusing on education and research.

Yet, these two organizations have much in common. Both recognize the fundamental nature of transportation services in support of economic development and improvements in quality of life. Both recognize the importance of the development of new technologies in continuing to advance transportation and the human enterprise. Both recognize the development of human resources through education and research as central to the responsibilities of large-scale industrial organizations.

So, while MIT and JR East have different responsibilities, in many ways the frame of reference that both organizations bring to the highly dynamic and challenging world of the latter part of the 20th century are similar indeed.

■ MIT Campus–center view of the Richard Cockbum MacLaurin Building

JR East—History

JR East was formed in 1987 as part of the restructuring of the Japanese National Railroad (JNR) into six passenger railroads and one nationwide freight railroad.

JR East is the largest of the six regional passenger railroads and, in fact, the largest passenger railroad in the world. It carries about 15 million passengers per day, runs 12,000 trains per day and generates 100 billion passenger-km per year. In the 8 years since JR East was formed, it has had good success on the dimensions of service, financial results and safety.

JR East has taken a very active role in the world of R&D with programs in many areas. JR East sees technology as an important component of its corporate strategy and further sees research as fundamental to its approach to the technological challenges in the railroad industry.

JR East is concerned with the development of the railway for the 21st century, the goal in safety of zero deaths and injuries and the provision of the fastest passenger service in the world. Further, it recognizes that the development of a highly-qualified cadre of transportation professionals capable of both operation of current technology and development of new technologies for the future is an important success factor for the company.

MIT—History

MIT is a major research university in the United States. It has about 10,000 students (4500 undergraduate and 5500 graduate students) and an annual budget for education and research of about $1 billion. Founded in 1861, MIT moved to the Cambridge campus in 1916 from Boston, and has developed important programs in education, research and public service.

The fundamental premise of MIT is that its educational and advanced research activities are closely linked. With its five schools (engineering, science, humanities and social science, architecture and urban planning, and management), the Institute has a long history of education and research in many fields. Although characterized by strong disciplinary programs, MIT focuses much attention on the

development of interdisciplinary linkages cutting across fields through various centers, laboratories and programs.

MIT is very much outwardly focused. Many have noted that MIT is not the 'ivory tower' that often characterizes academic enterprises. Rather, the tradition of MIT is to reach out to industry and government to apply innovative approaches to solving the problems of society for today and for tomorrow.

The MIT motto 'Heart and Mind' reflects a strong tradition of positive interaction between the Institute and industry around the world. MIT has a long history of cooperative research relationships with industry. For example, going back as far as the 1920s, MIT was central to the development of the technology that supports General Electric, one of the largest companies in the United States today. Numerous other examples could be cited of such interactions in industries such as manufacturing, communications, information systems, and automotives.

The transportation field is one area that MIT has emphasized in building cooperative relationships with industry. Close working relationships with firms in all major transportation modes, as well as government agencies concerned with transportation, have been a focus of MIT's activities. MIT has affiliate relationships with over 40 transportation companies and more than 20 government agencies concerned with transportation. And, in the increasingly international world of transportation, many of these organizations are outside the United States.

The JR East/MIT Partnership

In 1990 the leadership of JR East took the first steps in developing a partnership with MIT. During visits to MIT by Mr. Isamu Yamashita, then chairman of JR East, and Mr. Shuichiro Yamanouchi, then executive vice president, the conceptual framework for such a partnership was developed.

In a noteworthy and stimulating address early in 1991, Mr. Yamashita, speaking to the senior management of the School of Engineering at MIT, described "The Challenges of Privatization—Restructuring of the Japanese Railways and JR East Today." Mr. Yamashita emphasized the development of the human resources of JR East, the continued development of new technologies as a critical success factor for the railroad, and the importance of close ties between the research community and JR East. JR East, in a broadening of their perspective to the international research community, felt that reaching out to a technological institute such as MIT was an important strategic move.

MIT, for its part, recognized the similarities in perspective between it and JR East. An opportunity for cooperation with the largest passenger rail company in the world, a company with a technological point of view, and in an area—railroads and transportation—in which MIT had made an important commitment was well worth developing. The Institute had, in 1973, established a Center for Transportation Study (CTS) as an interdisciplinary program designed to develop research and education programs in the transportation sector. Further, railroad research had been a major focus of MIT's activity for years preceding the formation of CTS. MIT was designated as one of two Affiliated Laboratories of the Association of American Railroads in the USA in 1983 and has conducted advanced research and education in support of railroad industry programs, both in the USA and internationally.

JR East took the first steps in developing the partnership with MIT by endowing a senior faculty chair called the JR East Professorship. I had the great honor to be named as the first JR East Professor at MIT in September 1991.

Both JR East and MIT recognized that, while the establishment of the professorship was important, it was only a first step in the relationship between the two organizations. The professorship could provide the basis for cooperation but both organizations knew that much work remained to be done to develop a truly effective partnership between industry and academia.

The next important step was the Technoplaza held in Tokyo in September 1991. The Technoplaza, sponsored by JR East, was designed to show the technological innovations that JR East was working on as it developed its railroad for the 21st century. I was invited to the Technoplaza to accept the JR East professorship and to present my views on the JR East/MIT relationship.

My talk was on *Transportation, New Technology and the Railroads: A Broad Perspective*. This address

■ President and Mrs. (Rebecca) Charles Vest, Professor Joseph Sussman, Mr. Isamu Yamashita on the occasion of the World Economic Forum at MIT, Sept 1993

focused on two major themes:

1. The world of transportation is facing new and difficult challenges—but new technologies and concepts can and must be effectively utilized to address these challenges.
2. The above challenges imply the need for a new partnership between the transportation industry and transportation's academic community.

The talk drew upon thoughts of the great management scholar Peter Drucker in his landmark work of 30 years ago, *The Age of Discontinuity*. Drucker discussed major discontinuities in several areas. First, he noted that genuinely new technologies are upon us and acceleration in the development of these new technologies is a fact of life. He further noted that major changes in the international economy, with the world becoming one market, was an underlying principle for the future. Finally, Drucker noted that knowledge and its development is the crucial resource of the economy and for individual organizations within it.

While these ideas were written in 1960, they still ring very true and have great relevance for the world of transportation. To emphasize this, I discussed some of the critical transportation issues we face around the world. Among these issues is congestion at the urban, suburban and interurban level; the focus on productivity in both the developed and developing world, with implications for a tighter logistics cycle on an international scale; the changing face of the transportation industry as a whole due to changing organizational structures and relationships between the public and private sector; environmental and energy issues; and increased emphasis on safety.

■ Mr Isamu Yamashita (right) at the World Economic Forum *(Author)*

While these challenges are indeed difficult, we are also seeing technology and methodology expansions with dramatic consequences. Among the technologies and methodologies discussed were information sciences; communications; mathematical methods in operations research; materials and structures; robotics, automation and remote sensing; and organizational and economic theory.

The address noted that the fundamental challenge for the international world of transportation is to utilize these technological and methodological advances to address the critical transportation issues we face. It is only through an informed use of advanced technologies and methodologies that we can hope to deal with the need for superior transportation services in the future in support of a more productive set of national economies and a more productive world economy. There is a historical confluence of critical transportation issues with extraordinary change in a number of technological fields; our challenge is to take advantage of these new technologies. But, at the same time, we need to consider the subtle complex social, political and economic environment in which we work.

There are three specific dimensions to be considered.

1. Technology—the development and deployment of new transportation technologies.
2. Systems analysis—the use of analytic and economic methods to better understand the operation and control of transportation systems and its role in the economy.
3. Management and institutions—the recognition of the role of management and institutional factors in the implementation of transportation enterprises.

We need to consider all three—technology, systems and management—to achieve success in the future of the transportation enterprise.

The speech noted that research was a critical element in the transportation enterprise of the future and the education of what I call the "New Transportation Professional," able to address technological systems and institutional complexities of the future world of transportation, was central to the strategy. The development of this "New Transportation Professional," with expertise in new technologies as well as the broader systems and institutional perspectives on transportation, would require a new partnership for education and research between the transportation industry and the transportation academic community.

The contribution academia can make to this partnership relates to the new disciplines and concepts which must be integrated into the transportation field. What is needed is a transportation synthesis as an educational model for the 21st century to educate the transportation professional of the future.

On the international scene, we see this transportation synthesis as an expanding idea in academia. As the critical role of transportation in the productivity of nations becomes clearer and clearer, the broadly and deeply educated transportation professional becomes more and more essential.

Earlier, we commented that an expanded commitment to research in transportation will be necessary to meet the challenge of integrating new technologies and concepts into the transportation industry. It is important that the academic community be a full partner in this research enterprise. The transportation industry must support the innovative minds available in the academic community.

At the same time, academia must

be prepared to address its research supported by industry to the critical problems of industry. These industry-supported academic research programs must be truly joint ventures of academia and industry with a high degree of interaction. They would be carried out in parallel with the research programs performed by industry itself and would be complementary to these programs.

The development of research programs in transportation academia is important because it permits the development in the university setting of the new transportation synthesis, our new educational model. Research activities is the mechanism by which we integrate new technologies and concepts into our transportation education program, keeping them forward-looking and relevant to the transportation professionals of the 21st century.

For this partnership between industry and academia to prosper, both partners need to benefit. The transportation industry benefits through development of:

1. Broader based transportation education programs and practicing professionals with skills useful over long-term
2. Useful research programs complementary to own research activities

The academic community gains through:

1. Modernization of curricula
2. Better integration of research and education programs
3. Meaningful research programs on which to work
4. Resources necessary for these challenging tasks

I concluded my Technoplaza talk describing my vision of the partnership between JR East and MIT, which built on the insights of JR East's senior management; it involves cooperative research between MIT and JR East researchers, as well as education of JR East staff members.

With the conceptual framework now in place for the partnership between JR East and MIT, work could begin in earnest in developing a long-term program.

The next important step in the partnership was participation by JR East in the program of the Center for Advanced Engineering Studies (CAES) at MIT. In the 1991-92 academic year, JR East sent their first Fellow to the CAES program. This first Fellow is a senior researcher in the Safety Research Laboratory at JR East. During his time at MIT, he worked closely with a number of faculty, taking academic subjects, as well as discussing ideas for possible future cooperative research between JR East and MIT. His primary area of interest was risk assessment and his discussions with faculty, mainly Professor Amedeo Odoni and me, led eventually to the first cooperative research program between the two organizations.

After his return to Japan, MIT and JR East worked over the next year to carefully structure a cooperative work program in risk assessment. Patient development was needed to establish a program of cooperative research appropriate from both JR East's and MIT's perspective. Also, people in both organizations were cognizant of the fact that this research program was setting the structure for possible future areas of cooperative research and we wanted to be sure that what we proposed worked as a model for the future. This program began with a set of exploratory activities during the first year (September 1993 to August 1994) and continues now with an expanded set of research activities. Among the areas in the risk assessment program are:

- Development of safety indices for JR East operations
- Analysis of level-crossing safety from risk assessment perspective
- Derailment analyses
- Risk assessment perspective on earthquake sensing and train operating policies
- Construction program design
- Risk assessment in the context of 1995 Kobe earthquake
- Human factors analyses—rolling-stock maintenance from risk assessment perspective
- Hazards due to rainfall
- Signal overruns

Risk research is a joint and cooperative program between JR East and the Institute. The research agenda is developed jointly by JR East and MIT staff. MIT has had access to various JR East databases. In addition to the funding of MIT faculty and staff to conduct research, JR East, through the staff of the Safety Research Laboratory, is carrying on parallel activities in the area. Furthermore, there have been a number of meetings both in Tokyo and at MIT to discuss and further the risk research activity.

The risk assessment area was selected because it represents a long-term core interest of both JR East and MIT. JR East has established safety as its top priority. An effective investment in improved safety can take place only through sophisticated risk assessment analysis. MIT is one of the world leaders in the risk assessment framework, with advanced research in nuclear and transportation safety in its portfolio. So this research program built on basic and fundamental interests of both JR East and MIT. A number of research documents have been produced and it is expected that some of the findings of the research will be reflected in future JR East policies and practices.

JR East has continued sending a Fellow to the Center for Advanced Engineering Study each academic year. In total, five Fellows have been sent, focusing on areas such as natural hazards, geotechnical engineering and below-ground construction, risk aspects related to human factors, control systems, and reliability of electronic signaling devices.

Each of these CAES Fellows has proven to be an important communication link between JR East and MIT. All have developed their own research interests with faculty at the Institute. At the same time, they have served a liaison function, helping in the organization of technical meetings between JR East staffers and MIT faculty in a number of additional technical areas that may become joint research directions for the future.

In addition to the CAES Fellows, JR East has sent graduate students to study for degrees at MIT in the School of Engineering in the transportation

and construction fields, the Sloan School of Management and in Urban Studies and Planning. These graduate students have participated in the MIT Rail Research Group, which represents a broad range of railroad-related research activities at MIT, including the program with JR East, the Association of American Railroads Affiliated Lab at MIT, the Federal Railroad Administration of the US Department of Transportation, and individual railroads in the USA and abroad. By participation in this rail research group, the JR East staffers have been exposed, not only to the research programs directed toward their particular interest, but to a broad range of research activities in the railroad field.

In addition to the flow of people from JR East to MIT, MIT sends student interns to work at JR East. MIT students, with Japanese-language skills as well as technical credentials, have spent periods as short as a summer and up to 1 year working at JR East, contributing to their technological programs.

Further, a number of MIT faculty have visited JR East to give seminars, inspect JR East facilities and to participate in discussions of advanced research activities.

Thus, over the last few years, a number of relationships between individuals at JR East and MIT have been established. Important professional exchanges have taken place between a number of people from both organizations, providing the basis for long-term growth in the intellectual interchange.

A management structure for a long-term relationship is in place. Each year senior management from JR East meets with MIT faculty to discuss joint activities and to plan for the future. These meetings have proven to be very useful exchanges, as each organization seeks to assure that the concepts that defined the initial JR East/MIT partnership continue to be valid and that the particular activities that have been implemented are consistent with the long-term needs of both JR East and MIT.

At both JR East and MIT, emphasis has been placed on developing broad relationships encompassing many aspects of both organizations. These are shown in Table 1.

Table 1. Participating Groups

JR East	MIT
Technical Research and Development Department	**Academic Departments;** • Civil and Environmental Engineering • Mechanical Engineering • Aeronautics and Astronautics • Electrical Engineering and Computer Science • Sloan School of Management
Safety Research Laboratory	
Technical Center	
International Department	**Centers, Program and Laboratories;** • Center for Transportation Studies • Operations Research Center • Artificial Intelligence Laboratory • Center for Advanced Engineering Study • MIT Japan Program • Human-Machine Systems Laboratory • Industrial Liaison Program

The program is truly interdisciplinary. The interests and perspectives of diverse MIT and JR East Staff have come together to develop a truly broad-based program at the Institute.

The interdisciplinary nature of MIT's approach deserves special emphasis. While the institute aspires to the development of interdisciplinary programs, building them is no easy feat. The interdisciplinary approach to the JR East program has come together with remarkable swiftness which reflects JR East reaching out to a broad constituency within MIT.

The program has proven to be a broadening experience for both MIT and JR East. MIT faculty, students and staff have been exposed to a number of new perspectives in research areas in their interaction with peers at JR East. At the same time, a number of JR East professionals have gained by participation in the research and education programs at MIT.

One of the young professionals who came to MIT and earned a Master of Science in Transportation now works in the Technical Research and Development Department heading a group of six engineers concerned with environmental noise caused by high-speed-train operations. I found it particularly stimulating to talk with him during one of my recent visits to JR East, now that he has returned to professional responsibilities on the railroad. His most interesting statement, from MIT's viewpoint, was the comment he made about mentoring young Japanese engineers on the advantages of an international experience, and in particular an MIT experience, for their professional development. He indicated that he viewed it as his professional responsibility to explain to people working for him the professional advantages that can accrue from the kind of education and research environment provided at MIT.

As the relationship matures between MIT and JR East, we hope we can build a second generation of JR East staffers coming to the Institute, and certainly this person's experience and perspective gives us some cause for optimism in this regard.

From the opposite point of view, I have had extensive discussions with a MIT mechanical engineering graduate who served as an intern for 1 year at JR East working in the Technical Research and Development Department. This intern has also been very helpful in describing to MIT students considering working in Japan how productive and helpful an experience with JR East could be to their professional development.

It is clear that our two organizations have a great deal to learn from one another and that we have made great strides toward developing the personal ties needed to establish this joint learning experience.

Lessons

To date in its brief 5-year history, the JR East/MIT relationship has achieved a good deal. MIT has relationships with many Japanese companies in a number of industries. Senior officials at MIT have characterized this relationship as among the most successful.

Let us try to identify the lessons we have learned in building the JR East/MIT partnership.

1. The relationship should be built on the core interests of both organizations. In this case, the core interests of JR East in safety and appropriate investment therein and new technological development as well as development of their human resources were all supported by this program. MIT's core interests in educational program development and advanced technological research in the area of transportation were supported by the exchange.
2. Both MIT and JR East take a very long-term view of this relationship. Both feel that the first several years of the partnership is providing the basis for a variety of activities in the future. Investments both organizations make now in developing relationships and research contacts will bear fruit over a long time period.
3. The program has been multidimensional with individual components that are mutually supportive. For example, JR East staffers who have served as fellows at the Center for Advanced Engineering Studies at MIT have used their time at the Institute to develop research programs for later implementation. The JR East people who have come to MIT to study for graduate degrees participate in the broader based railroad research activity at MIT and subsequently can encourage other JR East people to participate in MIT programs.

   JR East-supported research activities at MIT can be integrated into MIT's educational programs and the interdisciplinary nature of the cooperative research provides a particularly useful input to development of the 'new transportation syntheses.'

4. The programs at both organizations are reinforced by complementary aspects in those organizations. For example, at MIT, the activities of the AAR Affiliated Laboratory directly benefit from the research activities with JR East. At JR East, the technology development activities in various organizations are supported by the MIT research and education programs.
5. There is interest in and support of the relationship at all levels of both organizations. At JR East, senior management has stayed active in its monitoring and shaping of the program. They have been supported in this by middle management and technical staffers at JR East as well who are direct participants in the relationship.

   At MIT, the senior levels of the Institute have had a continuing interest in building the relationship. Further a variety of faculty, staff and students are direct participants.

6. Personal contacts are very important in building relationships between complex organizations. Both MIT and JR East are large and complicated organizations. It is sometimes difficult even for people inside those organizations to fully understand them, never mind those people who are outside. To establish a truly productive partnership that draws upon the strengths of both organizations, personal relationships at various levels in those organizations are necessary.

   Both MIT and JR East have worked hard to establish personal communications and relationships between professionals. A number of MIT faculty have traveled to JR East, have traveled on the railroad, and have given seminars. Research meetings have been held both at MIT and at JR East, not only in the already established area of risk assessment, but in other areas that both organizations are considering for the future, such as microelectronic reliability, noise abatement, advanced construction methods, distributed information systems, etc.
   The MIT faculty makes an effort to involve JR East personnel on campus in a variety of professional activities, giving them a chance to develop a number of personal ties to Institute faculty.
   A strong organizational relationship, which both JR East and MIT aspire to, is based not only commitments from the senior levels, but also on personal relationships that are established. Both MIT and JR East recognize this and have worked hard to develop it.

7. Patience is needed to build a long-term relationship. Both MIT and JR East entered the relationship with a long-term commitment to make it succeed. However both organizations needed to be patient in building a relationship that could be sustained into the future. While there was conceptual agreement from the earliest stages, deciding on particular areas to pursue and how to pursue them took some time and considerable patience was needed on the part of those responsible for structuring a relationship that could last.

   Taking the time to learn about the other organization's needs, work styles, resources, and perspectives is a precondition for success.
   The risk assessment project is a good example of this. While this research program was identified in conceptual terms in 1992, it took a year of careful planning between MIT and JR East to establish a proper set of activities and an organizational framework within which both organizations could comfortably work. The time that we took to properly define the program and establish contacts will permit us to be more productive over the long term in developing this research area.
   Both JR East and MIT think in

terms of a program rather than a set of projects. Emphasis on the interconnections between the various aspects of the relationship has always been strong and opportunities are always sought to have these various program components effectively build on each other.

The integrated program aspect requires considerable time to build. It also suggests a need to build carefully, piece-by-piece, to insure the long-term viability of the program.

Chairman Yamashita, in discussions of this, noted the motto of "born small, grow large" to suggest that building the program slowly and carefully is important for the long term. Indeed, his advice is correct. The JR East relationship with MIT, which started small, has grown and proven to be strategically sustainable.

The Future

Where will the relationship between MIT and JR East go in the future? While we believe the basis has been built for a long-term cooperative program between the two organizations, the precise directions it will take are difficult to predict. There are a number of possible areas for mutual cooperation that have been established during many meetings between MIT and JR East staff. The question of which of these we will pursue is open at this time.

More importantly, the framework is in place. We know that success is based upon choosing areas that are core interests of both organizations as shown by the risk assessment project. Positive personal interactions have been established; these give us flexibility in selecting areas for future endeavor.

The current, most promising area for research cooperation is that of reliability of microelectronic devices used in signaling. The broadening of the research relationship to this area is illustrative of the JR East/MIT cooperative program. It deals with the utilization of important new technologies and in an area of fundamental importance to JR East—reliability of the signaling system. This new research area involves still more MIT people in the program—in this instance, faculty and staff from the Electrical Engineering and Computer Science Department and the Artificial Intelligence Laboratory. The research will be sponsored by the Technical Research and Development Department of JR East, expanding the program beyond the sponsorship of the Safety Research Laboratory.

Both organizations will continue to send people to visit and participate in programs at the other. Senior management of both organizations will continue to help guide the fundamental directions of the program, and we are confident that a solid basis for future cooperation has been established.

We are proud of what we have accomplished in working together, but there is much to accomplish in the future. The continuing challenge of privatization and changing markets for JR East and for the development of new research and educational programs by MIT provides a number of opportunities for cooperation between our two organizations. We should not relax and rest on our previous gains, but rather build on the infrastructure that we have established and build on the many personal relationships that have developed between people at MIT and JR East at all levels of both organizations. Our emphasis now should be on building upon those relationships for the joint success of both our organizations.

From my viewpoint, the partnership that JR East and MIT have built is important as a model because it ties together industry and academia in a 'traditional' field—transportation.

Conventional wisdom says that such cooperation is most viable with new high-tech firms. This relationship shows that firms in the transportation field require technology development and a new kind of professional for success in the future; JR East has recognized this and took the initiative in building a partnership with a major technological university. MIT, for its part, has recognized that traditional fields like transportation are vital (in the USA, it represents 18% of GNP) and that considerable attention should be directed toward them. This common understanding of the need for new technological development and upgrading human resources in the transportation field is the foundation of the JR East/MIT partnership.

We are convinced that partnerships between industry and academia in many areas of human endeavor are fundamental to world economic and environmental progress. We believe that the JR East/MIT relationship can be a prototype for such relationships. While JR East and MIT are different in mission, the core issues for both organizations are quite compatible. Building new human resources, and properly developing and deploying new technologies for the challenges of the 21st century are at the heart of what both organizations believe in. The basis for the partnership is there, but much hard work was and is needed to realize it. We at MIT look forward to many years of continued productive partnership with our friends at JR East.

Publications, speeches and presentations are listed below. ■

Publications

I. Reports and Articles

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II. Working Papers

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Ingólfsson, A., "Estimating the Probability of Rare Events," June 1994

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Yamashita, Isamu, "The Challenges of Privatization—Restructuring of the Japanese Railways and JR East Today," presented to the senior faculty, School of Engineering, MIT, Cambridge, Massachusetts, USA, June 1991

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Shimamura, Makoto, "Rail Research Activities at JR East," presented to MIT Rail Research Group, MIT, Cambridge, MA, USA, September 1994

Rimm-Kaufman, Alan, "A Mathematical Model to Predict Earthquake Damage to a Railroad," presented at JR East, Tokyo, Japan, July 1995

Anandarao, Sudhir, "Safety Analysis of Level Crossings," presented at JR East, Tokyo, Japan, July 1995

Horiuchi, Masahiko, "Research Programs at JR East—Recent Results," presented to MIT Rail Research Group, MIT, Cambridge, MA,USA, September 1995

Yamanouchi, Shuichiro, "Japanese Railroads in Transition—The Benefits and Lessons of Privatization, presented at the Symposium on Transportation Privatization: Potential and Reality, Center for Transportation Studies, MIT, Cambridge, MA, USA, November 1995

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Sussman, Joseph, *"Educating the New Transportation Professional"*, ITS Quarterly, 1995 Summer lssue, Vol. III, No.1

Participating MIT Faculty and Staff

Professor Arnold Barnett, Sloan School of Management, Operations Research Center

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