# Summary of the Association of American Railroads Future Search Technology Conference

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Railroads have only just started out on the quality journey, and achieving customer satisfaction will soon become a way of life. This new business attitude will be a driving factor in the railroads' future and will have a direct influence on technological developments.

The AAR Research and Test (R&T) Department is developing a new 5-year plan for its research activities. To begin this process, in March 1993, 71 invited participants attended a conference, Railroads in the 21st Century: Opportunities for Technological Innovation. A relatively new technique called future search conferencing was used at the meeting.

The future search technique is a carefully planned, structured workshop process. It takes advantage of highly participative group brainstorming to build cooperative, mutually supportive goals set by delegates from diverse interest groups. Each stakeholder group soon recognizes that its objectives will be best met by agreeing to a common vision of the future for the industry and working with peer groups to achieve it. Once the sense of common ground is achieved, new concepts, ideas, and the means to achieve the best of them flow. Group presentations and analysis of the key concepts promote enthusiastic support for plans and assignments that will help realize the groups' collective view of a desirable future.

Stakeholder groups at this conference consisted of customers (representing coal, grain, chemical, intermodal, and port authorities), railroads (strategic planning, operations, mechanical, engineering, and research functions), suppliers (of locomotives, cars, track equipment), academia, technical consultants, and AAR staff.

Participants began by examining the past and the present, and, using those lessons, learned to help generate a collective vision of the future of rail technology.

Customer satisfaction will be the driving force leading to the formation of multimodal, global, integrated transportation systems that provide seamless service. Scheduled, and sometimes faster, train service will be required, as will vastly improved service reliability.

Information technology and command, control, and communication technology will play major roles in providing customers, operating groups, and executive departments with correct and timely information from which effective planning, command, and control decisions can be made and executed to ensure that customer requirements are met. A number of specific recommendations were made to ensure that this goal is reached.

Increased emphasis on preventative maintenance for both track and rolling stock will be necessary to improve service reliability. Improved monitoring systems and techniques to predict maintenance requirements are needed. It was also considered desirable to build a "fit and forget" track structure that requires significantly less maintenance. The track structure and the trains that run on it must be designed with a view to optimizing performance of the whole system. Performance specifications are considered important in this system's engineering context, with a recognition of the need for performance standards to be broad enough to encourage innovation and accommodate new technologies.

Environmental issues played a major role at the conference. The need for new energy sources and power system technologies was highlighted for more efficient and cleaner systems to preserve the inherent environmental advantages of rail transportation over competitive modes.

Overall, considerable optimism was expressed for the future of rail transportation and the role that technology will play in that future. However, frustration at the relatively slow pace of technological change in the industry was expressed by many. Improved life-cycle costing techniques and better appreciation of life-cycle costing was seen by many as an essential ingredient for the acceleration of technological change.

The future search conference was the first of a three-step process to develop a new 5-year research plan for the Association of American Railroads (AAR). From AAR's perspective, the current conference, the Transportation Research Board Conference on Railroad Freight Transportation Research Needs, serves as the second step. The two conferences will provide more detailed input than is usually received in the research planning process. With the challenges that the industry faces, the research community must take full advantage of its scarce resources. Research programs need to be coordinated and be fully responsive to the needs of the industry. These conferences will play a major role in achieving that goal.

After this conference, AAR will consolidate the suggested approaches and seek further advice and counsel from its member railroads and the rest of the railroad community.

Major conclusions from the future search conference are summarized here. The opportunities for technological innovation drawn from that conference should provide important input, but certainly not the only input, to assist participants at this Conference on Railroad Freight Transportation Research Needs in achieving the goal of identifying railroad freight transportation research needs, opportunities, and priorities, for both the private and public sectors, during the next 10 to 15 years.

## Lessons from the Past

The first half-day of the AAR conference was designed to determine what lessons could be learned from the past in order to better shape the future. Three aspects of the past were examined: participants' personal and professional lives, world affairs during the past 3 decades, and the history of the railroad industry.

To some extent, the three topics were linked in the minds of the participants. For instance, on the personal level, the primary theme of the discussions was survivability. The individuals, the majority of whom were in the 30- to 50-year age bracket, survived world upheavals, with the Vietnam War prominent in many minds; personal and family crises and tragedies; and major downsizing and restructuring of the railroad industry. There was a feeling that survivors tend to have a good outlook on the future. Because of their past experiences, survivors are more comfortable with the change, growth, and risk that is inevitable as the railroad industry moves into the 20th century.

In examining the industry's past, all attendees participated in an exercise to list the major events that occurred before 1973, in the 10 years from 1973 to 1983, and from 1983 to the present. One group of participants collated this list, which is presented in the appendix to this paper.

These events were summarized by another group, which titled the pre-1973 phase as Power Brokers to Broke, as railroads moved from being the primary mode of transportation in the 19th century to fighting for survival by 1973. Technology played a major role in the glory years but, despite such advances as continuous welded rail and higher capacity freight cars, could not prevent the decline in market share or financial problems. The group noted that part of the railroads' decline could be attributed to failure to perceive customer needs and that the period ended with railroads having an inward focus.

The next phase (1973–1983) saw some major restructuring [e.g., the National Railroad Passenger Corporation (Amtrak) and Consolidated Rail Corporation (Conrail)] and deregulation through the Staggers Rail Act. The industry began to do more research, particularly through cooperative industry programs, to examine specific problem areas, such as tank car safety and track-train dynamics. Modal competitive pressure continued to increase, however, and the industry was just beginning to face up to its excessively costly labor and the need for major improvements in productivity.

The same group of conference participants labeled the last 10-year period as Reinventing Our Technology, highlighted by the improved productivity as fewer employees, locomotives, and cars accomplished more ton-miles of rail traffic movement. The decade was focused on safety, energy, and the environment and, in the past few years, on technologies involving enhanced information exchange, such as Automatic Equipment Identification (AEI) and Interline Service Management (ISM). The major reinvention, however, came with the emphasis on quality and responsiveness to customer needs.

How should this view of the past affect future thinking? The consensus was that there must be a continuing emphasis placed on working with railroad customers and working toward growth through quality. Partnerships with other transportation modes will expand and railroads will leverage advantages in energy and environmental considerations to promote traffic growth. New technologies must be pursued to maintain and improve this environmental advantage.

Technology must continue to help make productivity and safety improvements. Emphasis was placed on the requirement to balance technology needs with railroad operating plans, philosophies, and strategic business objectives.

## LESSONS FROM THE PRESENT

The second day of the conference began with a brainstorming exercise to determine which areas are of most concern to the industry at the present time. The group identified nine distinct, major trends influencing the present and future of the industry:

- Focus on customers,
- Customer satisfaction,
- Reliability,
- Infrastructure performance,
- Improved system engineering—trains and rolling stock,
- Highway congestion,
- Fuel conservation,
- Organized (computerized) information, and
- Technology.

Participants then met in groups organized on the basis of their stakeholder affiliations to assess the industry's capabilities as they relate to the present and the future of the industry. Each group was charged with examining three of these trends to determine opportunities for technological innovation. The groups' deliberations are discussed in the following sections.

### Focus on Customers and Customer Satisfaction

These two categories of trends are so closely related that it is appropriate to discuss them as one. It is interesting, but perhaps not surprising, to note that the stakeholder group of customers was far more critical of the current status of customer focus than most of the other groups. The customers believed that railroads still have a largely internal focus. They believed that railroads do not properly recognize their competition and that they measure performance by internal railroad standards.

One of the two groups of railroad suppliers also noted that railroads still have an internal focus, but the other industry groups were not as critical of the present situation. All other groups recognized the need for improvement, but noted that railroads are building an awareness of and focus on the customer, including moves toward scheduled train service, customer surveys, more tailored services and equipment, and the presence of railroad representatives in customer offices.

The customers and the rail industry groups were in good accord with what needs to happen in the future. Railroads must adopt an external focus and recognize customers' needs. More partnerships with customers are required. Railroads need to better understand customers' markets and the role of transportation in those markets. Railroad performance needs to be measured by customers' standards, and there was universal appreciation of the need for a seamless transportation system with the customer having only one point of contact. Technology components of this future trend will include improved service reliability, more custom trains designed in cooperation with the customer, and a closer working relationship between railroads and suppliers.

## Reliability

Three groups chose to study reliability. One major problem seen by customers is that dock-to-dock times are highly variable. This group regarded consistency of service as the primary goal for the future to ensure that promised delivery times are always achieved.

Other groups agreed that reliability must be improved, with failure-based maintenance being identified as a major cause of unreliability. There is relatively little preventative maintenance being performed. Systems need to be installed, both on-board and wayside, to constantly monitor conditions to enable maintenance management programs to be installed. It was also suggested that equipment needs to be specifically designed and purchased for reliability if major improvements are to be achieved.

Terminal operations were also cited as a reason for unreliability. A need for better terminal designs and advanced terminal operations and controls was recognized. The concept of reliability also extended to information processing, with recognition of the need for improved accuracy of data and information exchange and for a common communications platform, such as ISM.

## Infrastructure Performance

Five groups examined trends in infrastructure performance. The dominant theme was that the rationalization of the rail network has increased density and led to reduced opportunities for maintenance without interrupting service. Consequently, many of the predictions for the future were concentrated on ways to reduce maintenance frequency, including more robust track design (one group dubbed this "fit and forget" track), improved inspection and failure prediction techniques, and quicker, more automated track maintenance techniques and equipment. Techniques for extending the lives of bridges and for predicting those lives are required. Participants observed that current track maintenance practices tend to treat the symptoms of the failure and that far more attention must be paid to addressing the underlying causes of problems.

Track standards were another major theme. Concern was expressed that both regulatory and design standards are based on historical data and experience. It was also recognized that standards are often inconsistent and are not well coordinated with the requirements and limitations of rolling stock. Solutions for the future were based largely on the concept of developing performance standards, as opposed to design standards, with current and future rolling stock and business requirements in mind.

One other major theme was the perceived lack of life-cycle costing practices in the design of the track structure and in purchasing and maintenance decisions. More life-cycle costing tools are required.

## Improved System Engineering—Trains and Rolling Stock

One of the biggest problems identified by the four groups that examined this issue is that, for the most part, current rolling stock designs are evolutionary and bound by the interchange rules. Freight cars are designed as a series of specific subsystems, and, as a result, changes have been largely incremental. Participants agreed that vehicles must be designed to meaningful performance-based standards and should be designed as total systems instead of as a collection of components. Participants recognized that locomotive design is much more system oriented and that the next logical step is to design the whole train as a system. The High Productivity Integral Train (HPIT) program is a step in that direction, as are a number of other integral train designs.

Participants noted that innovation is often driven by technology, whereas it would be more appropriate for new designs to be market-driven, double-stack container cars being a good example. Equipment can also be subject to human failure; it should be designed for flawless operation.

Other observations included the need for an improved approval process for new car designs, more use of analytical techniques in vehicle design, better life-cycle costing to allow for purchasing for quality and reliability, and increased use of concurrent engineering techniques.

## Highway Congestion

Both groups that considered this subject recognized that highway congestion is increasing, particularly in urban areas, and that the highway infrastructure is deteriorating, yet pressure for larger and heavier trucks is mounting. More rail transportation is an obvious solution, but one drawback is that the public does not understand the value of rail transport. Both groups recommended a more proactive position in public policy with attempts to improve the image of railroads through public relations and through the press. More involvement in commuter rail, both on and off existing railroad property, will help to reduce highway congestion and improve the image of railroads. Continued progress in the elimination of railroad-highway crossings was also identified as an important element.

Several technological innovations were suggested for helping move highway traffic to rail. These included developing intermodal systems that are cost- and time-effective for the short hauls, increasing rail line capacity, improving access to ports and intermodal facilities, reducing railroad air emissions, and developing higher speed services.

## Fuel Conservation

There are a few ongoing developments in locomotive power, but the standard is head-end power based on direct current traction motor diesel-electric locomotives. This has been the standard for many years, although significant incremental changes have been made.

The group examining this issue foresaw several major changes having a dramatic effect on fuel conservation and environmental pollution. In the immediate future, they expect alternating current (AC) traction motors and natural gas fuel to be commonplace. Distributed power applications will be the norm, with greater use of power and improved horsepower matching to adhesion. Locomotive health monitoring technology is largely available now and will be used increasingly in the future.

In the more distant future, other technologies should be closely monitored. These technologies include fuel cells and methods to recover braking energy.

### Organized (Computerized) Information

The three groups that examined this topic all agreed that, although the industry was beginning to make the required changes, including the reengineering of some business processes, such as ISM, change is slow. Existing technologies from other industries should be used more extensively. Railroads develop systems or specifications for their own individual properties, whereas they should do more pooling of expertise and resources to develop common systems and standards.

For the future, the groups made a host of specific recommendations, including the following:

- Improve shipment-based tracking systems;
- Reengineer all business processes (car hire, etc.);
- Develop customer-based specifications;
- Develop systems to predict performance instead of monitoring failures;
- Normalize data in communications networks to reduce redundancy;
- Create and enforce data quality standards;
- Use expert systems more;
- Establish industry architectures for locomotive and train diagnostics, messages, and communications, including newer communications technology; and
- Integrate geographic information systems technology.

### Technology

One group tackled this broad subject and concluded that acceptance and implementation of new technology in the railroad industry are slow. Software and data systems technology are underappreciated. Design specifications and standards are typically based on current technology at best and on outdated technology in many cases. The group observed that there are relatively few suppliers to the industry and little sharing of technology exists.

A number of technical successes have been implemented rapidly, including continuous welded rail, improved rail steel, double-stack and articulated freight cars, rail grinding and lubrication, and better track performance. However, many technology gaps remain. Time constraints prevented development of a full list, but a few needed developments in technology that were identified included signalling system improvements, alternatives to wood ties, planning and controls for operations and service, and electronic data interchange (EDI).

Some general areas of technology improvement were identified for the future, including increased use of artificial intelligence, automation, and robotics. Increased efforts were recommended to transfer technology from other industries (aviation, shipping, and manufacturing were mentioned), including the use of pilot projects or demonstrations. Performance specifications allowing for future technology, thus requiring expandability and flexibility, were suggested.

## "Prouds and Sorries"

In this session, each stakeholder group was asked to identify the three events or trends of which it was most proud and the three for which it was most sorry. This exercise produced a long list. However, it is interesting to note that the top three "prouds" and the top three "sorries" of all the groups aggregated had similar themes. These three topics are probably of the most importance to the attendees.

The first topic was quality and customer focus. Groups that listed this topic at the top of their "prouds" list were pleased that railroads had begun the quality journey and were starting to develop an improved customer focus. Those that listed this topic at the top of the "sorries" list were frustrated that progress in this area is not quick enough and that a strong internal focus still exists.

The second topic was technological innovation. Some of the groups were proud that unit-train technology had brought about significant economies of scale and that double-stack trains had played a major role in capturing intermodal business. This view was balanced by four groups that expressed frustration that the rate of acceptance of new technologies is painfully slow.

The third topic is profitability and market share. The same groups that lauded unit-train economics of scale and intermodal growth were balanced by those bemoaning low railroad profits and low overall market share.

## FUTURE

Having discussed the past and the present to identify some opportunities for the future, conference attendees met in groups of representatives from various stakeholders to develop and act out short scenario themes of what the industry would look like in the year 2013. In addition to providing entertainment, the short skits identified 12 major themes for the perceived future of the industry:

- Accurate, timely information systems;
- Multimodal, global, integrated transportation services and products;
- Improved safety and reliability;
- Sophisticated command and control systems;
- Customized equipment and materials design and use;
- Automation of equipment;
- High-performance infrastructure;
- Beneficial impact on people and the environment;
- Advanced power systems and new energy sources;
- Improved train performance with integration of rolling stock and track systems;
- Greater emphasis on moving people by trains; and
- Human resource programs, particularly for retraining and cross-training.

The third day of the conference was devoted to further examination of most of these themes, including development of a problem definition and a statement of the impact on the railroad industry. Where appropriate, an action plan was developed to begin the work of achieving these goals. Eight groups were formed; a brief overview of each group's deliberations follows.

### Infrastructure

#### *Problem Definition*

Railroad professionals need to design, develop, and implement a transparent infrastructure that is a defect free, low maintenance system for long-life track. Ergonomically friendly tools and self-diagnostic equipment with automatic defect free signal systems must be developed. A long-range life-cycle cost-effective system must be environmentally friendly.

#### *Impact on Railroad Industry*

Railroad professionals must change their view of how track is purchased, installed, and maintained. This track infrastructure system will facilitate and enhance train operations and be integrated with improvements in rolling stock. The system will incorporate systematic training with automatic built-in safety tools and procedures.

The implementation of this goal will produce the desired operationally transparent infrastructure to help permit seamless, customer-responsive transportation.

### *Action Plan*

The group determined that the primary goals should be to design, develop, and implement a transparent turnout system and transparent rail. These were the two goals with the most opportunities for advancement to "fit and forget" track structures. To achieve these goals, a series of action steps was identified that included evaluation of optimum geometry and material characteristics and development and implementation of cost models.

## Rolling Stock and Materials Design

### *Problem Definition*

Railroad professionals need to design and build equipment for the railroads and private car owners that meets the needs of the customer and enhances the customer's competitive position.

### *Impact on Railroad Industry*

The customer's competitive position will be enhanced, totally satisfying needs while achieving the lowest overall system transportation cost (use, maintenance, first cost, fuel efficiency, track and infrastructure damage) and reducing the impact on the environment.

### *Action Plan*

Achievement of the goal is envisioned as a four-stage process. The first would be determination of the needs of the customers, which would include formation of joint shipper-railroad-supplier teams. The second stage would require development of relevant and accurate performance standards that would ensure safe operation, not impede innovation, and promote streamlined certification procedures and processes. The performance standards must include the ability to monitor equipment condition to allow intervention before catastrophic failure. Monitoring could include use of on-board devices in combination with wayside or shop equipment and software embodying algorithms that predict failure of components. The third stage would include further development of analytical tools to determine the lowest overall system cost over the life of the equipment and assessment of nondollar quantifiable and qualitative impacts. The fourth stage would involve development of a system to track components on cars, such as wheels, bearings, side bearings, brake equipment, and the like, in order to monitor their maintenance history.

## Improved Trains

### *Problem Definition*

The industry needs to develop a strategy to integrate and implement improved technology and materials in trains to maximize customer and railroad economic performance.

### *Impact on Railroad Industry*

A customer-focused process should be developed to rapidly respond to market requirements and opportunities for improving and designing trains (locomotives and cars) and their associated systems (electric brakes, trucks, etc.) with consideration of the track. (Market is defined here as including economic, safety, customer, and environmental considerations.)

### *Action Plan*

A multistep process was suggested to achieve the goal, beginning with determining customer needs. Next steps are to determine a finance and risk-sharing plan (including effective life-cycle cost models) and eliminate barriers, which includes developing strategies to minimize liabilities.

Other steps recommended include developing a systems integration plan (trainline data standard, interfaces for condition monitoring) and a plan to optimize the train and system dynamics through development of performance specifications. Finally, it will be necessary to develop a general implementation strategy, one that includes a rapid approval process.

## Commuter Rail

### *Problem Definition*

The industry needs to expand existing commuter service and develop new starts to decrease reliance on automobiles and the highway congestion and pollution that results from that reliance. Railroads must compete with automobile alternatives in cost, speed, reliability, convenience, comfort, and security.

### *Impact on Railroad Industry*

The impact on the railroad industry involves the following:

- Opportunity to share costs;
- Liability issues;
- Integration of freight and commuter operations;
- Dealing with public agencies, municipalities, and regulations;
- Additional staff; and
- Customer service (recognizing that people are not a commodity).

### *Action Plan*

A rail passenger research conference should be convened to develop a research agenda for the passenger rail industry. A plan was also suggested for increasing government support for long-term commuter rail capital and operating subsidies at federal, state, and local levels of government.

## Command and Control and Information Systems

### *Problem Definition*

Customers and carriers do not possess or effectively share the information needed to plan and execute reliable seamless service.

### *Impact on Railroad Industry*

Provide the customer, operating groups, and executive departments correct and timely information from which effective planning, command, and control decisions can be made and executed to ensure that customer requirements are being met. This will satisfy customer requirements by making systems more effective and efficient, which will result in regained market share.

### *Action Plan*

After considerable discussion, it was decided that the group could not develop a cohesive action plan on its own without close cooperation with activities already under way. Thus it was proposed to form a task force (or incorporate into an existing task force) to define an institutional and conceptual framework and a program to achieve the long-term goal.

## Integrated Transport Systems

### *Problem Definition*

How to create a global, integrated, multimodal distribution system in which a customer contacts one person or identity that takes responsibility from origin to destination for a given movement.

### *Impact on Railroad Industry*

The impact on the railroad industry involves the following:

- Larger market shares,
- Identification of legal issues,
- Financial requirements (e.g., lease or buy),
- Relations between labor and management,
- Lower total costs,
- Cooperation with current and future competitors,
- Bridging international boundaries,
- Command and control of equipment, and
- Risk and liability issues.

### *Action Plan*

It was suggested that AAR conduct a study to benchmark other global, multimodal transportation company processes, such as in the airline industry and Federal Express. The major responsibility lies with railroads to develop corporate strategies for the future.

## Energy Sources and Power Systems

### *Problem Definition*

Transportation systems that are powered by safe, reliable, more efficient, cleaner sources and that have lower life-cycle costs are needed.

### *Impact on Railroad Industry*

In the evaluation of the impact on the railroad industry, the following topics were discussed: global competitiveness, better environmental citizenship, increased autonomy (operationally), and improved service reliability.

### *Action Plan*

The group recommended evaluating an array of potential power sources, including electrical, solar and wind, fuel cells, flywheels, natural gas, hydrogen, linear induction, coal, and other alternatives. The plan included developing a program and funding for research and potential demonstration projects and implementation. It was recognized that external funding sources would be needed to advance many of the technologies.

### People and the Environment

#### *Problem Definition*

The short- and long-term adverse impacts of railroad operations on people and the environment need to be assessed and reduced. "People" includes all persons in contact with or affected by railroad operations—employees, customers, and the public.

#### *Impact on Railroad Industry*

Railroads need to differentiate between (a) routine air emissions, wastewater discharges, and the generation and disposal of solid and hazardous wastes and (b) occasional, or nonroutine, release to the environment of hazardous materials and oil as a result of spills and derailments. Both routine emissions and discharges and occasional releases have the potential for adverse impacts on people and the environment.

#### *Action Plan*

The group determined a need to ensure that new equipment and operations are reviewed for short- and long-term environmental and safety impacts to prevent further problems. It was noted that most current activity is associated with fixing or correcting current problems. A research and development review process is needed to identify potential human and environmental impacts of proposed equipment and operational changes.

## SUMMARY

The dominant theme of the conference was clearly the rapid movement toward much improved customer focus and the need to continuously satisfy customers' needs. Participants were convinced that railroads had only just started out on the quality journey and that achieving customer satisfaction will become a way of life. This new business attitude will be a major driving factor in the railroads' future and will manifest itself in many ways. These manifestations will include the following:

- Formation of multimodal, global, integrated transportation systems to provide seamless service to customers;
- Scheduled train services and vastly improved service reliability;
- Faster trains in some cases; and
- More joint customer-railroad-supplier teams to ensure that customer expectations are met or exceeded.

Information technology will play a major role in providing the seamless service that customers need. Although the industry is beginning to make the required moves, including reengineering some business practices by methods such as ISM, change is slow and there is much to be done. A number of specific recommendations were made, including enforcement of data quality standards, improved shipment-based tracking systems, and development of systems to predict performance instead of monitoring failures.

It was recognized that command, control, and communication technology is closely linked to the information technology requirements. In that regard, systems are needed to provide the customer, operating groups, and executive departments correct and timely information from which effective planning, command, and control decisions can be made and executed to ensure that customer requirements are being met.

More preventative maintenance activities and procedures will become common if railroads are to achieve the service reliability performance that customers will demand. This theme was present in both track and rolling stock discussions and provides for major technological opportunities in continuous monitoring of track and equipment. This monitoring should not be to merely detect failures but should become part of overall systems to determine optimum maintenance practices and schedules to prevent failures. The use of expert systems was a recurring theme in these discussions. Concern about bridge life and recurring maintenance on other parts of the infrastructure resulted in the determination that the track structure must be designed to last longer. This concept was named "fit and forget" track structure.

System engineering practices were regarded as an essential part of the future of railroad technology. Freight cars need to be designed as systems instead of as a collection of separate components. Trains need to be designed as systems to achieve optimum locomotive and freight car performance. The whole track and train system needs a better systems engineering approach, with each being designed with an appreciation of the need to optimize the whole system. More moves toward performance standards were predicted, particularly performance standards broad enough to encourage innovation and accommodate new technologies. Those performance standards should be driven not necessarily by technology but by the market and by customer needs.

Environmental issues also played a dominant role in the conference. Although it was recognized that rail transportation has inherent environmental advantages over its main competition, there was a strong feeling that the industry needs to be more proactive in exploiting this advantage. Railroads need to better identify potential human and environmental impacts of proposed equipment and operational changes. They need transportation systems that are powered by safe, reliable, more efficient, cleaner sources with lower life-cycle costs. A number of technologies were listed as being worthy of consideration, including electrical, solar and wind, fuel cells, flywheels, natural gas, hydrogen, linear induction, and coal.

Partly because of environmental concerns caused by extreme urban congestion, increased participation by freight railroads in commuter rail operations is anticipated.

Overall, considerable optimism was expressed for the future of rail transportation and the role that technology will play. There was a strong recommendation to ensure that advanced technologies, such as new materials, robotics, automation, expert systems, and others developed in nonrail industries, were monitored and adapted as appropriate to provide implementable products.

Despite this optimism, a certain amount of frustration was expressed at the relatively slow pace of technological change in the railroad industry. Improved life-cycle costing techniques and a better appreciation of life-cycle costing were seen by many as essential ingredients for the acceleration of technological change. These improved costing techniques are needed by researchers, manufacturers, and railroads to better determine the true value of different technologies.