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International Symposium on

Motor Carrier Transportation

Williamsburg, Virginia
May 31–June 4, 1993

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Foreword

The purpose of the TRB International Symposium on Motor Carrier Transportation, held in Williamsburg, Virginia, May 31–June 4, 1993, was to provide a forum for an international audience on motor carrier transportation issues involving government policy makers and regulators, researchers, academia, and representatives of the large truck goods industry, including suppliers, manufacturers, and motor carriers. The symposium focused on a wide range of technical, economic, safety, and environmental issues, as well as on the opportunities for greater efficiency and productivity for the motor carrier transportation community into the 21st century. The symposium was intended to foster productive communication among groups representing various disciplines in the private and public sectors whose problems and issues related to the motor carrier industry often conflict or coincide. Achieving such communication in an industry as decentralized as the motor carrier industry and among groups not accustomed to talking with one another is useful but often difficult. A major goal of the symposium was to begin fostering better communication between policy makers and the industry nationally and internationally.

The concept for the symposium was initiated by TRB's standing Committee on Motor Vehicle Size and Weight. As plans developed for the symposium, formal sponsorship was provided by three organizations: American Automobile Manufacturers Association (formerly Motor Vehicle Manufacturers Association), Federal Highway Administration, and National Highway Traffic Safety Administration. A number of other cooperating organizations also provided support for the symposium and are listed in the Acknowledgments.

The symposium was structured into five general sessions plus opening and closing plenary sessions. The opening session included six presentations providing *International Perspectives on Motor Carrier Transportation*, which are summarized in the first section of this Proceedings. Each of the other five sections of this Proceedings corresponds to the general sessions. The structure of each general session included a plenary session featuring a keynote address; presentation of one or more formal, peer-reviewed papers; and a panel discussion. After the plenary session, the participants were divided into four workshop groups, which allowed a more detailed discussion of technical issues and were helpful in identifying potential public and private actions and research needed to address them.

As the symposium progressed, the overriding theme that emerged was *change*: the motor carrier industry is experiencing a time of radical changes that will force it to develop new adaptive strategies to maximize opportunities presented by these changes. Change is not

unique to the motor carrier industry: nearly every area of the transportation industry is experiencing change that will be crucial to future truck and highway design and motor carrier operations. Examples include the North American Free Trade Agreement (NAFTA), which many believe will greatly increase productivity, enhance investment potential, and increase job opportunities for all of North America—but not without the growing pains from international harmonization of regulations and operations. Continuing implementation of the Intermodal Surface Transportation Efficiency Act of 1991, or ISTEA, aimed at strengthening the industry's international competitive posture while improving safety and environmental conditions, presents both enormous challenges and opportunities for motor carriers.

In meeting these challenges and taking advantage of these opportunities, the symposium discussions focused on the need for a variety of partnerships, some of which are well developed and others that require future development:

- Government and industry cooperation means sharing data and research.
- Highway and vehicle engineers, policy makers, and manufacturers need to communicate with each other and with the public.
- NAFTA challenges include the standardization of size and weight limits.
- Intelligent vehicle-highway system technology requires partnerships for development and implementation.
- Intermodal challenges exist, but each mode will ultimately find its most efficient role.
- Shipper-carrier partnerships, intermodal partnerships, and partnerships between carriers will increase efficiency and reduce total logistics costs to create a seamless transportation system.

Other issues and themes emerging from this symposium include the following: safety and efficiency go hand in hand; new technologies present new possibilities; environmental issues demand more attention; balance is needed between states' rights and national interests (relative to safety and productivity); driver training should be improved and standardized and more attention paid to driver working conditions and career aspirations; and many research issues require additional or improved data, the collection of which can be improved using smart technologies.

TRB's standing Committee on Motor Vehicle Size and Weight has established a research subcommittee to use the material from this Proceedings in identifying key truck weight and dimension issues and developing research needs to address these issues.

International Perspectives on Motor Carrier Transportation

Richard B. Robertson, *International Road Federation*
Jack Pénissard, *International Road Transport Union*
Robert A. Pearson, *National Road Transport Commission, Australia*
Joseph F. Canny, *U.S. Department of Transportation*
Derek Sweet, *Transport Canada*
Donald R. Beall, *Rockwell International Corporation*

As the chief executive officer of the International Road Federation, Richard Robertson noted the existence of a common set of issues around the world regarding motor carrier concerns; the problem or controversy comes into play with policy implementation regarding these issues. He cited five reasons that problems occur:

- Differing priority structures, especially in underdeveloped countries (e.g., matters of environment, safety, and aesthetics are subordinate to establishing a route for the delivery of goods).
- Precedence. What has happened in the past largely determines what will happen in the future. Governments are often unwilling to simply discard old structures.
- Politics. The right of self-determination causes resistance to change.
- Lack of revenue to meet needs.
- Knowledge. There is no consensus on motor carrier issues, such as proper axle loading, truck design, and other policy questions.

Robertson touched on problems and progress in Mexico and the United States. Mexico has made great strides, including impressive toll road development and other technological improvements, but financing problems exist because of the high interest rates. Rates have jumped to an unreasonably high level to cover costs and to make toll roads self-sustaining. However, Mexico's improving credibility in the international arena should mitigate the financing problem in time. A more difficult task will be that of monitoring truck weights so that new roads are not ruined. Currently, no reasonable limits exist.

In the United States during the Reagan Administration, transportation policy was driven by the following factors: cost responsibility, states' rights, and productivity. During those years, policy makers were reluctant to place national interests over states' rights; however, when productivity was being compromised, the government stepped in to enact overriding legislation. Government interference, even when compelled by this important issue of productivity, can lead to conflicting and inconsistent policy goals, Robertson noted.

The main theme of Robertson's speech was the need for national standards to govern trucking operations. He advocated a strong North American Free Trade Agreement (NAFTA) to help Canada, Mexico, and the United States realize their collective potential. This potential depends on the maximum possible harmonization of highway design, bridge design, size and

weight controls, commercial driver's licenses, safety procedures, taxation, regulation, enforcement, and customs, along with a need for each country to "get its own act together."

Robertson advocated pursuing, at minimum, the following goals to achieve an effective highway system and motor carrier industry:

- Improved productivity,
- Increased safety,
- System integrity,
- Cost responsibility, and
- Equitable enforcement.

To maintain highways and improve productivity, accurate information must be obtained and analyzed, thus avoiding costlier problems down the road. Robertson believes that the federal government should mandate three experimental techniques that would override states' rights in ensuring the collection of pertinent highway traffic data used to prevent road deterioration: automatic vehicle identification, weigh in motion, and automatic vehicle classification. One result of this policy would be equitable enforcement among all classes of carriers without regard to the size of their operation.

Robertson advocated the same approach toward operational issues: that truckers would be subject to requirements of only one driver's license, one safety inspection, one tax, and so on. Strong action at the national level is needed to ensure that a uniform policy is enacted in all states.

Robertson closed his speech by referencing Martin Luther King's famous line, "I have a dream." His dream is that one day a trucker with one license, one insurance policy, and one safety inspection can travel cross country without having to stop except to eat and sleep. He would like to see the same dream come true for Canada and Mexico.

Jack Pénissard opened his discussion by noting that since the founding of the International Road Transport Union (IRU) in 1948, the motor carrier industry has become the world's leading land carrier in tonnage, number of passengers carried, and value of goods transported; and that because of its success, it has borne the brunt of much criticism, often unjustified. The IRU acts as the international forum and spokesperson for national road transport associations; its presence has become even more crucial now that international and even intercontinental travel and transport have become such important factors.

The IRU is a private confederation bringing together and defending the interests of 148 associations of passenger and goods road transport operators in 57 countries. The topic of Pénissard's speech was an examination of recent developments in road transport in Europe, with particular emphasis on the countries of Central and Eastern Europe, including the former Soviet Union. Matters addressed included several regulations and directives promoted by the European Community (EC) Commission to forward the goals of European integration and freedom to provide services.

Pénissard pointed out that transportation policy is just one of the sectoral policies without which European integration is impossible. Progress made in the area of road transportation involves the removal of obstacles to freedom to provide services (i.e., the free movement of persons, goods, and services) and the reduction or elimination of regulatory distortions of competition.

As a result of new regulation, all professional transportation operations between member states of the EC is cleared through one community license with no quotas. Discriminatory restrictions for transporting goods between member states have been abolished, with licenses issued on the basis of a carrier's financial and professional integrity.

Pénissard also went into great detail on "cabotage," which refers to authorizing a carrier in one member state to effect domestic transportation operations in another member state even if the carrier does not have a registered office there. The EC Commission strongly advocates the total liberation of cabotage as part of ensuring complete freedom to provide services.

Pénissard then discussed several EC regulations that, without compromising productivity, attempt to create more uniform standards for the weight and dimensions of commercial vehicles and for driving and rest times. He believes that the trend of new regulations and directives boosts progress for the EC transportation industry.

Freedom of movement, EC enlargement, and relations with countries not members of the EC are now taking priority over consolidation of existing legislation. In addition, the collapse of the Soviet Union and the decline in industrial production in other Central and Eastern European countries, such as the former Czechoslovakia, Hungary, Poland, and Romania, have had a dramatic effect on the EC transportation industry. The emerging pattern of trade is proving advantageous to road transportation, which is better positioned and more flexible than rail; however, economic difficulties are having a deleterious effect on all goods transportation. Commercial potential exists for Central and Eastern Europe but will require an improved infrastructure (modernization of routes), Western involvement, and training.

In conclusion, Pénissard remarked that road transportation, long held back, is developing strength through the new initiatives designed to support it. (Rail transportation, however, is in decline because of poor commercial operation and logistics organization.) The fall of the Iron Curtain has also contributed to the opening of exciting opportunities; road transportation, in particular, must accommodate this new departure.

Robert Pearson outlined problems in Australia and indicated their similarity to those already mentioned:

- Inconsistent standards and regulations that add to cost,
- Administrative inefficiencies,
- Shopping around,
- Safety concerns, and
- Scope for improvements in production.

Contrary to the U.S. situation, Australian interstate regulation cannot address these problems because it deals only with vehicles engaged *solely* in interstate trade. One intrastate journey by a carrier would exclude it from coverage by national interstate regulations.

The process of cooperation among states and territories having prime responsibility for transportation regulations had failed to provide uniformity in motor carrier regulations. Heads of government decided that furthering the reform process called for the formation of an independent "umpire," which led to the formation of the National Road Transport Commission (NRTC). The founding principle of NRTC was that the recommendations made by the commission must be disproved by the council of nine ministers to which the commission reports or the recommendations become law. This new process aims at solving the inefficiencies created by states' rights in Australia.

The role of NRTC is to facilitate improvements in both road safety and transport efficiency as well as to reduce the administrative costs of road transportation. This requires uniform or consistent legislation on road transportation regulations and taxing of trucks and buses. Challenges ahead include improving vehicle productivity, rationalizing driver working hours (hours of service), and creating technical standards such as those pertaining to braking and road-worthiness (out-of-service rules).

Pearson said one current strategy relies on the provision of incentives as a way to elicit desirable outcomes, such as those related to road-friendly suspensions or driver working hours. Once incentives are in place, a team management approach will be used.

Australia relies heavily on trucks sourced from both North America and Europe. NRTC, therefore, has a strong desire for international harmonization on safety standards and plans to lend its full cooperation to movements designed to strengthen uniformity.

Joseph Canny substituted for Transportation Secretary Peña in addressing the array of challenges and opportunities facing the U.S. trucking industry. Specifically, he discussed NAFTA, the environment, safety, and other issues of infrastructure, productivity, and labor as major topics under consideration.

On NAFTA, Canny believes that the signing of this treaty in December 1993 will mean greatly increased productivity, enhanced investment potential, strengthened international competitive posture for all of North America, and increased job opportunities. He pointed out that because Mexico's current motor carrier foreign investment policies are more restrictive than those in the United States, designing parallel liberalization schedules was difficult. Acknowledging the concern expressed by some that opening up investment opportunities to Mexico will disadvantage U.S. carriers, Canny pointed out that joint ventures will help establish new markets for both countries and that the Mexico trucking industry's relatively weak financial structure and lower sophistication are unlikely to allow Mexican carriers to expand quickly into the U.S. marketplace.

On harmonization, a second key NAFTA issue, Canny cited mutual recognition agreements between the United States and both Mexico and Canada on commercial driver's licenses as a step in the right direction toward harmonization. Over the long term, he added, consistent, compatible safety standards in the three countries will facilitate enforcement—reducing the burden imposed on border states—and ensure full equipment compatibility.

Canny specified global climate change and air quality as the two most pertinent environmental issues to be addressed by the transportation industry, which itself plays an important part in the overall picture. The transportation sector now contributes more than 30 percent of the U.S. domestic output of the predominant greenhouse gas, carbon dioxide (CO_2). Although recent legislation is beneficial in helping to address the problem, more stringent measures for increasing efficiency and modifying operations will be needed to bring down CO_2 emissions, said Canny.

Addressing air quality concerns, Canny cited the Clean Air Act Amendments (CAAA) of 1990, which included new, lower standards for particulate matter (PM10) and nitrogen oxide emissions for diesel trucks. Under CAAA, each state is responsible for developing and implementing a plan for meeting overall air quality standards for PM10, nitrogen oxide, carbon monoxide, and ozone in those areas currently not in attainment. Transportation control measures can be a key portion of state air quality plans, said Canny.

As for safety, Canny said that there is good news and bad news. The good news is that the truck fatal accident rate decreased by 40 percent between 1978 and 1990; the bad news is that the number of truck-related fatalities remained the same. Noting efforts under way to combat this problem, Canny pointed to the Motor Carrier Safety Assistance Program, the Commercial Driver's License program, and a U.S. Department of Transportation safety rating program as important public-sector initiatives. Trucking industry initiatives have included computerized trip recorders, proximity radar, driver training programs, and more sophisticated screening of driver applications. Much room for improvement remains, Canny asserted, particularly with respect to human factors and the role of technology.

Other issues addressed by Canny included infrastructure and productivity and the ways in which the two are inextricably linked. Desired infrastructure results are related to increased

funding for pavement research and testing, investigation into contractor guarantees and warranties to build high-quality highways, research into ways to make trucks more operator-friendly and roads more durable, and higher levels of investment in highways. Canny noted that advances in technology and management techniques will improve the productivity of the trucking industry. The reduction of unnecessary government regulation should also be a goal, he said. On a final note, Canny asked whether the United States is applying intelligent strategies to deal with driver issues, in particular driver shortages. While noting that some carriers are providing in-house drivers' schools, coordinating dispatching to get drivers home more often, and finding ways to instill driver loyalty, he also suggested that other issues may need to be examined; these include level of compensation, job security, and hours worked per week.

In presenting a Canadian view of the future of motor carrier and highway transportation, Derek Sweet noted the similarity of Canadian and U.S. challenges. These included NAFTA and other implications of sweeping global changes:

- New approaches in both the private and public sectors. Governments must let market forces dominate. The three NAFTA parties have all undertaken measures to promote economic regulatory reform, Sweet noted.
- The redefining of transportation competitiveness in the future. Shippers are concerned and must increasingly concern themselves with overall transportation cost and service quality.

In Canadian developments, Sweet said that in the 5 years since Canada deregulated the trucking industry in 1988, safety standards have been consolidated into a National Safety Code. The process is still not complete but offers compatibility with standards in the United States and eventually Mexico. Sweet said that the Canadian government last year reexamined its transportation policy, with the resulting recommendations:

- No compelling reason exists to continue the residual economic regulation of the trucking industry; economic control at the provincial level is minimal in all but a couple of cases.
- Deregulation is working. Efforts should be strengthened to achieve uniformity in trucking rules and enforcement in the areas of safety and other regulatory areas such as weights and dimensions.
- Deregulation of the bus industry is recommended.
- The principle of user-pay should be applied, being one of several developments prompting discussion about the federal role in highway infrastructure.

Sweet said that the federal government supported provincial highway development in the past but in recent years has done so only to fulfill specific goals of regional or resource development. Recent developments relating to federal involvement include the following:

- The federal government and the provinces have defined a national highway system.
- The federal government has recently committed about $800 million in highway investments over the next 5 years, mainly on cost-shared projects with the provinces.
- The federal minister of transportation and his provincial colleagues will take a fresh look at innovative means of funding national system improvements.

Addressing recent Canadian internal trade policy, Sweet said that the Canadian federal system has fostered regional protectionist policies that inhibit trade; now the federal government is pushing for a comprehensive removal of barriers, and the provinces have agreed to

come to the table. Offered for discussion will be uniformity of motor carrier safety standards and vehicle weights and dimensions, bus deregulation, and intraprovincial truck economic regulation.

As for international trade, Sweet noted that since the inauguration of the Canada–United States Free Trade Agreement in 1989, Canadian–U.S. trade has risen despite the generally depressed economies of both countries during that period. He predicted that NAFTA will no doubt contribute to the growth in the transborder market. He added that it will be important to have a review mechanism in place to enable all parties to resolve problems and to facilitate orderly implementation.

For a better future, efficient transportation services will be paramount, summarized Sweet, adding that NAFTA will increase trade opportunities and that Canadian carriers will have to innovate to keep pace with evolving market demands. Echoing the advice given at the Symposium to U.S. carriers, Sweet said Canadian carriers must (a) develop innovative management strategies; (b) apply high-quality, service-oriented techniques and systems; and (c) implement appropriate technologies to enhance productivity.

Government will play an important role in promoting the harmonization of standards and a level playing field that encourages cost-effective services—both needed to be competitive in the North American market. Sweet closed by touting Transport Canada's initiative in taking up the leadership challenge through an increased emphasis on consultations with industry and governments and by promoting a climate of partnership with shippers, carriers, and federal and provincial interests.

Donald Beall's discussion recounted the tremendous challenge and change faced by the motor carrier industry across a broad range of issues, including those related to economic cycles, trade policy, technology, and environment. His recommendation for companies facing this new environment was to "think globally and act locally"—in other words, understand the array of existing and potential markets and customers and commit to staying close to those customers in every way.

Beall pointed out that companies must manage their businesses in a highly cyclical industry worldwide and that this environment, although turbulent, offers promise for the industrious entrepreneur. Opportunities worldwide are also being enhanced by changing trade agreements, said Beall, citing NAFTA and "Europe 1992" as examples.

He described technology as another challenge with the potential to transform the motor carrier industry and lower prices for consumers. Technology is also helping this industry redefine itself as a transportation system, not just as the trucking business. Defense-related technologies, in particular, can play an important role. Integrating these technologies into a business with commercially developed marketing and production expertise can result in transportation products and systems that customers value. Some enabling electronics and defense technologies with transportation applications include sensors, communications, signal processing, controllers, decision tools, and electronic displays, which have led to the development in recent years of on-board computers, satellite communications, and other intelligent vehicle-highway systems. Beall emphasized that the key to success in business will not be the technology itself but the ways in which data and systems are managed.

In turning to the environment, Beall focused on the congestion question, saying that the issue will drive increased intermodal transportation.

In citing Rockwell's "lessons learned," Beall said that first and foremost, suppliers must be there when customers need them. The motor carrier industry needs to be flexible in adapting to a business world with different standards, vehicle configurations, and road systems from one place to the next.

Another lesson of today's global economy, according to Beall, is to look outside the traditional business base to new markets. It is also necessary to be farsighted enough to

anticipate the needs of customers and potential customers for new products and added value. And companies must increasingly examine how they are organized internally and how they design work processes. "More and more, we're reducing layers of management, pushing down decision-making authority, and focusing on team-building and continuous process improvement," said Beall, all of which reduce costs and improve productivity. Beall indicated team-based approaches as being an effective method of improving productivity.

Beall cited the Intermodal Surface Transportation Efficiency Act of 1991 and NAFTA as clearing a path for growth of the nation's transportation infrastructure, saying that any steps taken to improve the ability of companies to compete on a worldwide basis will, in the long run, stimulate job creation in the United States, Canada, and Mexico. NAFTA, he said, is a "win-win" situation for everyone.

In summary, Beall reiterated the changing times in which the trucking industry finds itself. Success will require improving quality and product cycle time, reducing cost, and increasing flexibility, productivity, and safety—all of which add up to value for the customer. "Those who see this industry as mature and tranquil do so at their own risk," he said.

PRESENT AND FUTURE GOODS PRODUCTION, LOGISTICS, AND MOTOR CARRIER OPERATIONS

Keynote Address

Donald A. Pais, *General Motors Corporation*

Donald Pais's address centered on the fundamental theme of change; the ability of a business to anticipate and adapt to change determines its success. The motor carrier industry is the lifeline to our nation and must be proactive, not reactionary, in responding to changing demographics and economies, which, in turn, elicit different customer requirements and needs. According to Pais, this means a paradigm shift for the motor carrier industry in the form of "step-function" improvements, which—because they represent big changes—are difficult to implement because of the comfortable limitations that old paradigms provide. Major paradigm shifts require establishing new boundaries and new behaviors for operating within them.

It is easy for companies and human beings to get "trapped within their own paradigms," Pais noted. Examples can be seen in the inability of NCR (National Cash Register) to anticipate electronic cash register technology or the delay of Sony to see the potential of laser disk technology for consumer music.

Just as the automobile industry shifted from thinking "quality is expensive" to "increased quality will reduce costs and reduce waste," the needed paradigm shift for the motor carrier industry will involve a change from "reducing total time in transit is expensive" to "reducing total time in transit reduces cost," said Pais. To effect this paradigm, two factors must be considered: speed and idle time. Speed can be improved by better use of technology, but this alone will not produce significant change. The factors affecting idle time must also be examined, such as limits on a drivers' hours, double handling, wait time, and so on. All are potential inefficiencies that can be improved. Changing manufacturers' needs will require smaller lot sizes and more frequent deliveries. In sum, Pais thinks that transportation should be seen as just one element of a total manufacturing process supported by synchronous material flow.

For the transportation industry, the talking points to remember when making step-function changes include the following:

- A manufacturing lot size of one,
- Material continually moving,
- Value added at every step, and
- Manufacturing's dependence on transportation to move even the smallest lot with the highest frequency and speed possible.

Future Manufacturing, Markets, and Logistics Needs

John J. Coyle, *Pennsylvania State University*

In 1962 Peter Drucker discussed the logistics-distribution area in an article entitled "The Economy's Dark Continent," referring to it as the last frontier for significant cost reduction. In describing the situation then, Drucker made the following observations:

> Distribution is one of the most sadly neglected but most promising areas of American Business. . . . We know little more about distribution today than Napoleon's contemporaries knew about the interior of Africa. We know it's there, and we know it's big; and that's about all. . . . Most of our present concepts focus on production or on the stream of money and credit, rather than on the flow of physical goods and its economic characteristics. . . . To get control of distribution, therefore, requires seeing—and managing—it as a distinct dimension of business and as a property of product and process rather than as a collection of technical jobs.
>
> The industrial purchaser has to know his own business . . . he has to know what the product or supply he buys is supposed to contribute to his company's end results. . . . My purpose is to point to distribution as an area where intelligence and hard work can produce substantial results for American business. Above all, there is a need for a new orientation—one that gives distribution the importance in business design, business planning and business policy its costs warrant. (*1*,p.103)

Reflecting on the developments in logistics and transportation since 1962, one may be tempted to use the line of a popular advertisement: "We've come a long way." Logistics and transportation have indeed come a long way, and there are many signs of successful achievement. For example, the number of major manufacturing and service companies represented by individuals with titles of vice president or director of logistics, distribution, materials management, or transportation has increased dramatically, as have the responsibilities and salaries of such individuals (2,pp.120–130). The membership of one of the best known logistics organizations, the Council of Logistics Management, has swelled to more than 7,000 active members and another 40,000 members who periodically attend the annual meetings of the organization.

Despite the significant developments that have occurred in logistics and distribution since World War II, logistics and transportation are still in a period of growth and development, as depicted in Figure 1 (2,pp.124–125). For many companies, 15 to 25 percent of the cost of their manufactured products goes to cover the expenses incurred before an item gets to or after it leaves the production line: transportation, inventory, warehousing, packaging, and materials

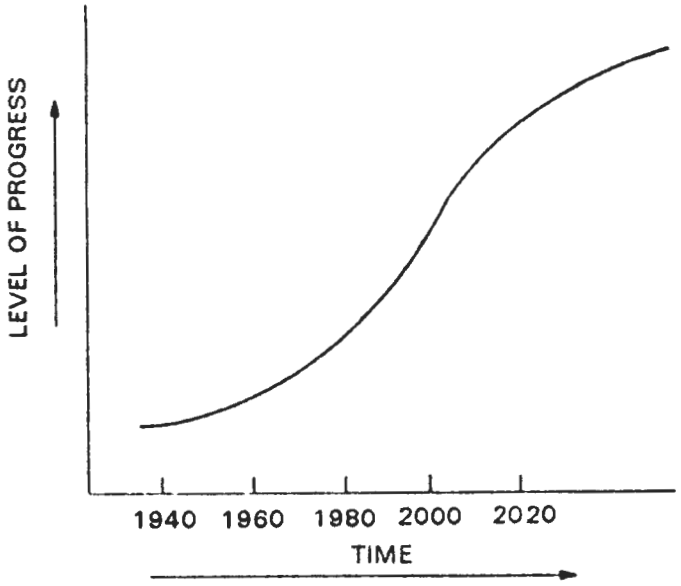

FIGURE 1 Development of importance of logistics and distribution in U.S. companies (*34*,p.2).

handling. For service companies, the costs are often higher (*3*,pp.8–12). One U.S. automobile producer, for example, spent more than $3 billion on transportation alone in 1990 (see Table 1).

The 1970s could be classified as the decade for products and markets, and the 1980s as the decade for finance. Many individuals believe that the 1990s will be the decade for transportation and logistics because gaining and maintaining access to a customer base and significant market share are the focus of strategic thinking and planning in big and small organizations (*3*,pp.10–14). Logistics and transportation can play an important role in helping achieve such strategic objectives (*4*,pp.21–24).

The 1980s was a decade of prosperity and growth, but it was also a period of turbulence and upheaval that resulted in a transformation in the ways in which materials, products, and services moved through the supply chain from vendors to manufacturers to customers. Of particular note has been the shifts in relationships among distribution channel members, especially the increased economic leverage of large retailers such as Wal-Mart and Toys-R-Us, and the growth in importance of the entire service sector. Increasing sophistication of all buyers, industrial and consumer, with their insistence and quality and value has also contributed to the transformation (*4*,pp.38–39). But the 1990s will be even more significant in terms of change in the U.S. economy and the distribution system that will be needed to support it (*5*).

In the next section, the logistics concept will be examined to provide additional insight into understanding the needs of shippers in the 1990s and the general nature of the demand for transportation services. The impact of the logistics concept will be illustrated by research done on the use of larger equipment size by shippers. The section on the logistics concept will be followed by a discussion of the major change agents (drivers) that continue to dictate distribution system requirements in the 1990s. Next will follow an examination of some macro data that will underscore the impact of the logistics changes of the 1980s. Following the examination of the macro data will be a discussion of critical factors for shipper success in the 1990s. The final section will summarize the transportation strategies of shippers and their impact on freight movements in the United States.

Logistics Concept

History

The origins of the modern logistics concept in businesses can be traced to developments in military logistics during World War II (*6*,pp.2–6.) The recent Persian Gulf War again demon-

TABLE 1 Major Transportation Purchasers, 1991 (*35*,p.15)

Rank	Company	'90 Tab ($)
1	General Motors	3,450,000,000
2	Ford	3,000,000,000
3	Chrysler	1,000,000,000
4	International Paper	1,000,000,000
5	U.S. Steel	734,200,000
6	General Electric	700,000,000
7	Dow Chemical	670,000,000
8	PPG	478,000,000
9	Shell	382,000,000
10	Bethlehem Steel	374,000,000
11	LTV Steel	352,300,000
12	Union Carbide	340,000,000
13	Alcoa	300,000,000
14	FMC	263,000,000
15	J.I. Case	220,000,000

strated the importance of logistics to a successful military effort. In fact, the Persian Gulf effort has been referred to as the "logistics war," and the importance of the integrated logistics pipeline supporting the fighting effort was acknowledged repeatedly by the military and civilian leadership. The integrated logistics concept was obviously critical to the military's success in the Gulf War. That same concept, while not new, has also been receiving increased attention in the private sector in the 1990s (*3*,pp.28–30).

One of the most widely used and cited definitions of logistics is as follows:

> Logistics is the process of planning, implementing and controlling the efficient, effective flow and storage of raw materials, in-process inventory, finished goods, services and related information from point of origin to point of consumption (including inbound, outbound, internal, and external movements) for the purpose of conforming to customer requirements. (*6*)

Implied in the definition is that the logistics process provides a systems framework for decision making that integrates transportation, inventory levels, warehousing space, materials handling systems, packaging, and other related activities and encompasses appropriate trade-offs involving cost and service. Another definition suggests that logistics involves the efficient and effective management of inventory whether in motion or at rest to satisfy customer requirements and organizational objectives (*6*,p.10). The important aspect of the latter definition is that transportation service is recognized as inventory in motion; therefore, the true transport cost is more than the actual rate charged by the transportation company.

To gain some additional perspective on the importance of the integrated logistics concept and how it has affected business organizations, the Dow Chemical Company will be used as an illustrative example (*7*,pp.173–176). The Dow Chemical Company is a diversified manufacturer of basic chemicals, plastics, specialty products, and services and produces and sells more than 1,800 products that can be categorized into four major groups: basic chemicals, basic plastics, industrial specialties, and consumer specialties. Many different formulations of these products are packaged in many different containers at 28 manufacturing locations in the United States. These products can be distributed through any one or a combination of 350 stocking points.

Since Dow is highly integrated, the supplier for raw materials for one manufacturing process is often another Dow plant. Managing work-in-process inventories is not difficult, but manag-

ing finished goods inventories is complex and challenging. Many of the finished products must be in inventory when customer orders are received. Just the size and complexity of the logistics network makes managing it extremely difficult, but other factors add to the problem (7,p.177). Traditionally, for example, the product supply chain of manufacturer, distributor, and supplier worked independently of one another trying to anticipate demand, but without real visibility into the future demand from the other links in the chain. Inventory was used to buffer uncertainty at each step, which resulted in large inventories at plant and field warehouses (7,p.175).

Computer systems are now being used to substitute information for inventory all along the supply chain. Each link works with the same demand information properly offset by time and rounding quantities. The result is that each link in the supply chain provides a time-phased schedule of the demand that it expects to place on the next link.

Demand forecasting is used to anticipate customer demand. Some customers may provide estimates of demand, leaving forecasting to anticipate the rest. Distribution requirements planning (DRP) considers inventory position, translates forecasts into realistic shipping quantities and schedules, and then consolidates that demand at each shipping point in the distribution network, ultimately to the plants. Master production scheduling (MPS) systems are used to translate schedules of DRP demand into feasible master schedules of when finished goods will be produced. The master schedule puts demands on raw materials. So materials requirements planning (MRP) translates master schedules into a schedule of when raw materials need to arrive from the suppliers.

Computer systems also support the flow of materials and products along the supply chain. Purchasing and transportation systems supported by electronic data interchange (EDI) manage the flow of material from vendors. Technologies such as computer-aided design and manufacturing and automatic materials handling systems support the manufacturing process. Deployment planning, vehicle load management, and vehicle routing and scheduling systems plan the movement of products from plants to warehouses to customers. The benefits from using an integrated systems approach to supply and demand have allowed Dow to reduce its logistics costs on a relative basis and improve its customer service.

Much more could be added about the results of integrated logistics at companies such as Dow, but hopefully enough perspective has been provided to show that companies want to attain high levels of customer service yet reduce inventory levels and transportation costs at the same time. The improvement of customer service and the reduction of logistics costs would have been described as contradictory 10 years ago, but not today. Logistics and transportation systems in the leading organizations are achieving these apparently contradictory goals by strategic management of their logistics systems (7,p.178).

As indicated, modes are being chosen using a selection framework based on an integrated set of logistics-related factors. Decisions are no longer based simply on transportation cost (rates). Other factors can influence the decision. As part of the research effort for this paper, an examination was made of how a logistics framework would influence a shipper's decision to take advantage of lower rates with larger shipment tenders made possible by larger equipment sizes of motor carriers (*8*).

Application

The purpose of the research was to assess the opportunity cost associated with the additional inventory resulting from shipping and receiving larger order sizes. Given the current trend toward lowering inventory levels, the impact of longer combination vehicles (LCVs) on inventory was considered to be a relevant issue for analysis. The research used combinations of actual product values, shipment weights, densities, and distances that were examined to determine if inventory costs increased to the point that they offset the savings in transportation costs. Higher product values and larger shipment sizes usually increase average inventory levels and carrying costs.

Given the inventory-transportation trade-off, the question is whether the increased capacity will be used if carriers do offer larger vehicle capacities to shippers at lower rates. The trade-off approach necessitated by this systems perspective necessitates analyzing the impact of inventory on the total cost of logistics.

The first step was to test various shipment alternatives and their inventory-transportation cost trade-offs, which was done by running many hypothetical shipping scenarios using a simulation model developed at Pennsylvania State University to test the sensitivity to an assortment of variables: product value, freight rate level, demand volumes, carrying cost rates, and so on. For each variable, a range of values was run through the model to help identify which commodity and traffic lane characteristics most influenced the inventory carrying costs associated with larger vehicles (shipments).

The next step was to select a variety of shipper commodity groups to include in the survey. The commodity groups selected reflect a wide spectrum of shipping characteristics (Table 2). The commodity groups possessed a diversity of weights, densities, and product values. Moreover, 1987 Census of Transportation data showed that these 12 groups represented a significant percentage of total U.S. commodity flows.

Each shipper selected received a questionnaire that requested information pertaining to its specific transportation and logistics characteristics, and the shippers were asked to include data for high-volume products currently moving by full truckload (TL). The information requested included product values, inventory carrying costs, freight rates, line-haul distances, annual volumes, and order costs. The range of each of these six variables for the shippers surveyed is summarized in Table 3, showing product variables. As can be seen, there was a wide range with most of the variables.

- *Product value* is based on a company's price charged to its best customer ordering in full TL quantities. In many industries the terminology for this price structure is "bracket pricing." It reflects the best price to the best customer using the most economical shipping vehicle of the shipper. From an accounting standpoint, it represents the cost at the end of the manufacturing line plus a percentage markup.
- *Shipment size* incorporates two factors. The first is the size of the shipping vehicle. The larger the vehicle, the more freight it can carry (if not restricted by weight). The second factor is the physical characteristics of each commodity. Compare a packaged cereal shipment to a chemical shipment: the cereal is light and bulky and, because the physical dimensions of the trailer, will reach the cubic capacity before it reaches the weight capacity of the trailer;

TABLE 2 Industry Presentation of Survey Participants

SIC	Description
(01)	Agricultural Products
(20)	Food & Kindred Products
(21)	Tobacco
(22)	Textile Mill Products
(25)	Furniture & Fixtures
(26)	Paper & Allied Products
(28)	Chemicals & Allied Products
(32)	Stone, Clay & Glass Products
(33)	Primary Metal Industries
(34)	Fabricated Metal Products
(35)	Industrial Machinery & Equipment
(50)	Wholesale-Durable Goods

SIC: Standard Industrial Code Representation

TABLE 3 Product Variables Range of Values

Variable	Hi/Lo Values
Product Value	$0.18 - $52.00 per lb.
Inventory Carrying Cost	10% - 30%
Fixed Order Cost	$13.00 - $63.71
Freight Rate	$0.99 - $3.86
Shipping Distance	75 - 2,716 miles
Annual Volume	12 - 1,740 tklds.

conversely, the chemical product is usually packaged in drums and has a weight density (pounds per cubic foot) that creates shipments that "weigh out" before they "cube out" in standard dry van equipment.

- *Shipping distance* reflects the distance from the point of origin to the point of destination. The origin and destination for all products are from a plant to another plant or distribution center. One important reason for this selection is because moves from plant to plant/distribution center are typically done in single-commodity TL shipments.
- *Product weight density* is expressed on the basis of weight per shipping unit (sacks, drums, or cases). This variable affects the total amount of a product that a company can legally load and transport in a trailer. The maximum TL quantity also depends on the interior physical dimensions (cubic carrying capacity or volume) and weight limitations of the shipping vehicle. A product with low weight density makes more efficient use of the added cubic capacity afforded by the LCVs.
- *Inventory carrying cost* reflects the corporate cost of holding inventory at origin and destination. Total inventory carrying costs will vary depending on the value of the product in inventory and the rate calculated for carrying inventory (current interest, property tax, and insurance rates).
- *Freight rate* expresses the flat charge of the shipment based on shipment distance or shipment weight and is usually expressed by dollar per mile or hundredweight. Freight costs, along with inventory carrying costs, typically make up the major share of total logistics costs. Most of the shippers surveyed used carriers that quote rates on a per-mile basis. For ease of analysis and consistency, rates were converted and expressed in the per-mile format.
- *Annual lane volume* in units and hundredweight was furnished by each company. This permitted the entering of various demand levels into the simulation model to analyze the impact of annual demand on the total logistics cost for each vehicle type.
- *Fixed order cost per shipment* reflects the cost of processing an order at the origin. It reflects the cost of the paperwork and information transfer to the shipper. Total order costs will vary by vehicle type. A standard 48-ft trailer would have to make twice as many trips as a double 48-ft trailer combination to meet the same annual lane volume, which would mean twice as many orders.

To illustrate the impact of the variables, four case studies based on data obtained from shippers were developed (Table 4, Figures 2 through 9). For each scenario, three shipment configurations were used: 48-ft TL, 48-ft/28-ft LCV, and 48-ft/48-ft LCV. The last two represent LCV movements, which are larger shipment sizes than currently being used and would provide lower rates because of carrier productivity. The 48-ft TL shipment was considered standard. For each case, total logistics costs (freight, inventory carrying cost, and order costs) associated with the three shipment configurations are shown, followed by a presentation of what has been labeled the break-even rate. The break-even rate is the rate that could be charged by each configuration to equalize the total logistics cost of all three.

In Case 1, the variables are mostly in the middle range for each category but the product value is relatively low. The simulation model shows that the twin 48-ft LCV would provide

TABLE 4 Values for Cases 1–4

CASE	PRODUCT VALUE ($/lb)	INVENTORY CARRYING COST (%)	FIXED ORDER COST ($)	FREIGHT RATE ($/mi)	SHIPPING DISTANCE (mi)	ANNUAL VOLUME (48-ft TLs)
1	2.70	20.25	37.74	1.30	300	100
2	4.03	18.00	35.00	1.10	734	12
3	1.47	20.00	25.00	1.75	617	52
4	12.76	20.25	25.00	1.80	300	55

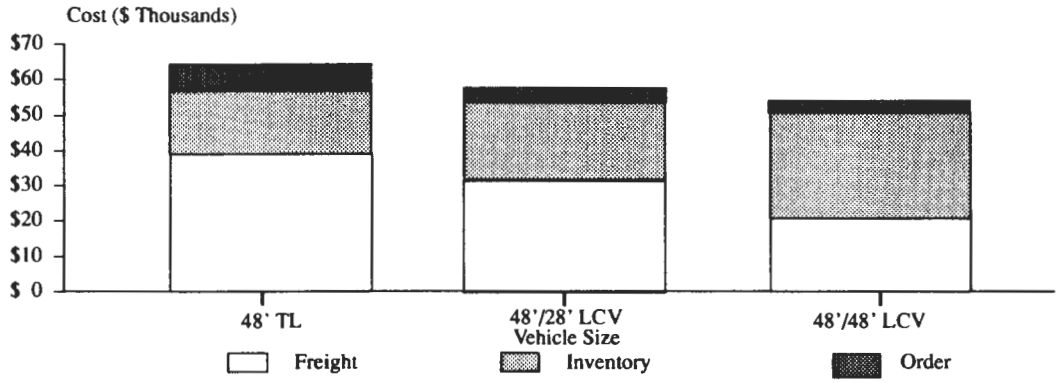

FIGURE 2 Comparison of costs by vehicle size, Case 1.

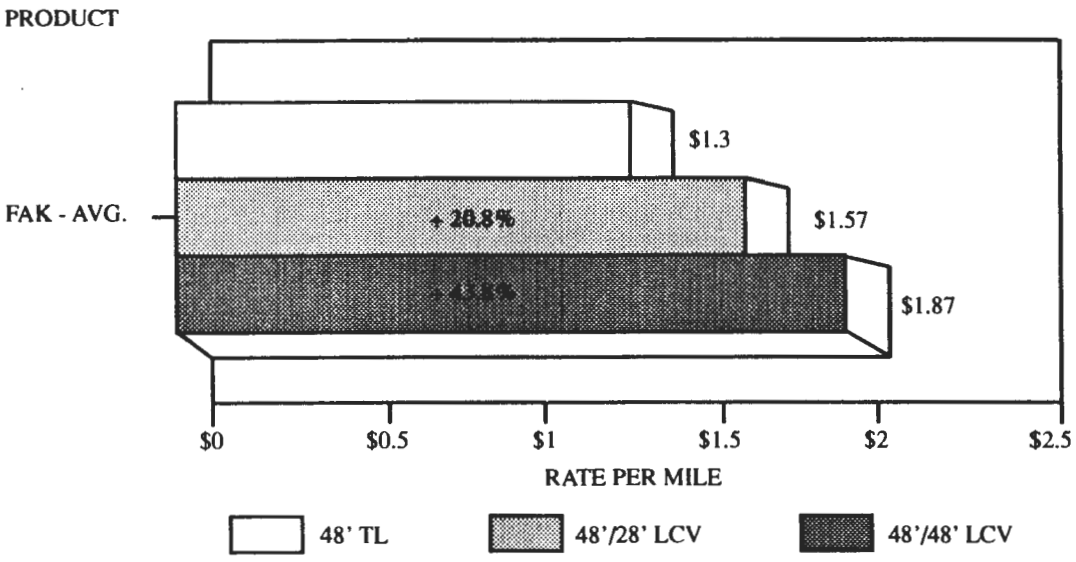

FIGURE 3 Break-even freight rates, Case 1.

the lowest total logistics costs and that the transportation rate on this configuration could increase by 43.8 percent over the single 48-ft trailer before total logistics costs would be equal.

Case 2 represents a shipment situation with higher product value, longer distance, and less volume. In this case, the 48-ft standard trailer would provide the lowest total logistics cost because the inventory carrying costs are so high relatively. Interestingly, the twin 48-ft could offer a zero transportation rate, and total logistics costs would still be lower for the 48-ft trailer paying $1.10/mi.

Case 3 has low product value and relatively long shipment distance. Here, the twin 48-ft LCV again provides the lowest total cost, and there could be an 88.6 percent increase in the

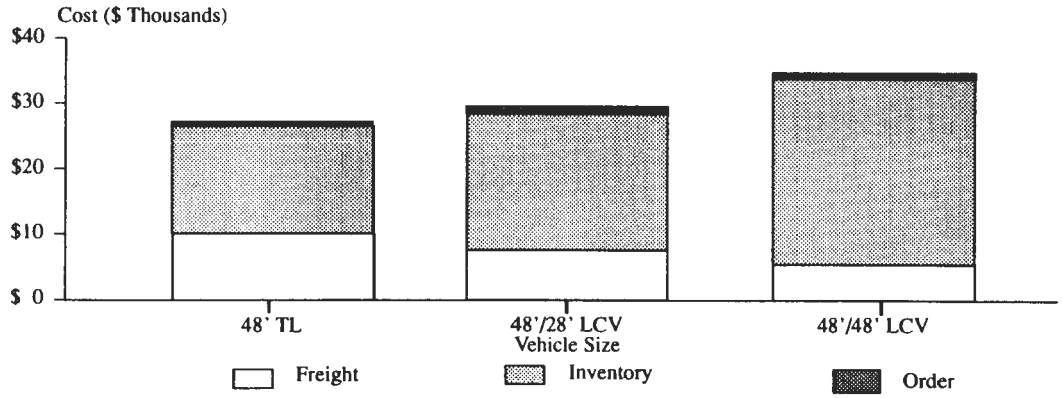

FIGURE 4 Comparison of costs by vehicle size, Case 2.

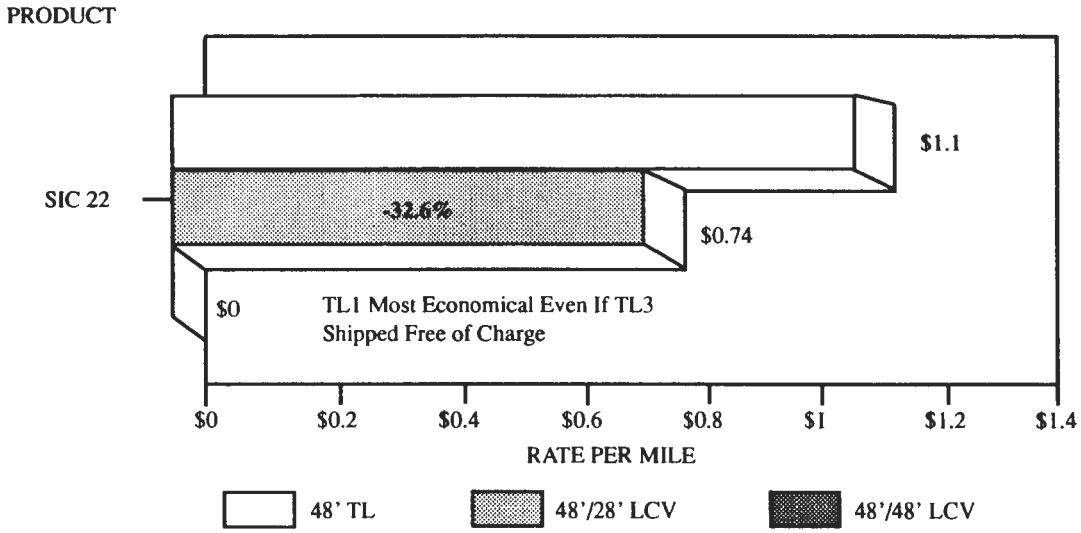

FIGURE 5 Break-even freight rates, Case 2.

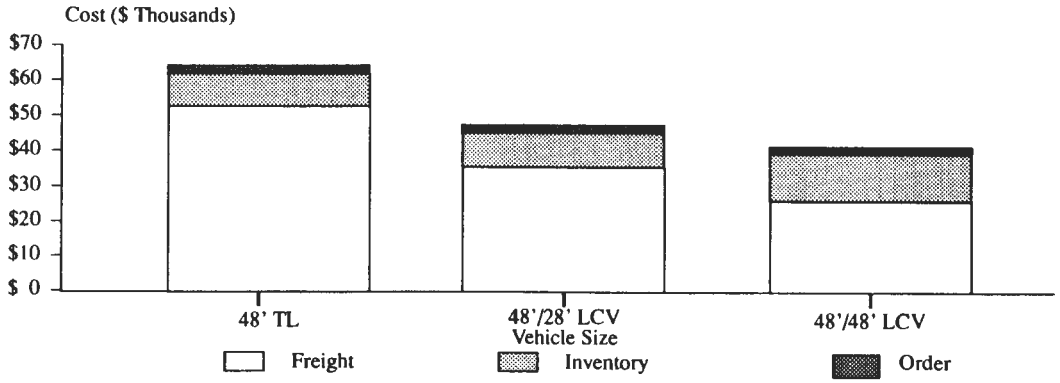

FIGURE 6 Comparison of costs by vehicle size, Case 3.

rate, from $1.75 to $3.30/mi, before total logistics costs would be equalized with the single 48-ft configuration.

Case 4 illustrates a situation with high product value and lower shipment distance. Consequently, the single 48-ft configuration provides the lowest total cost. Again, even if transportation were free, the double 48-ft LCV would give a higher total logistics cost.

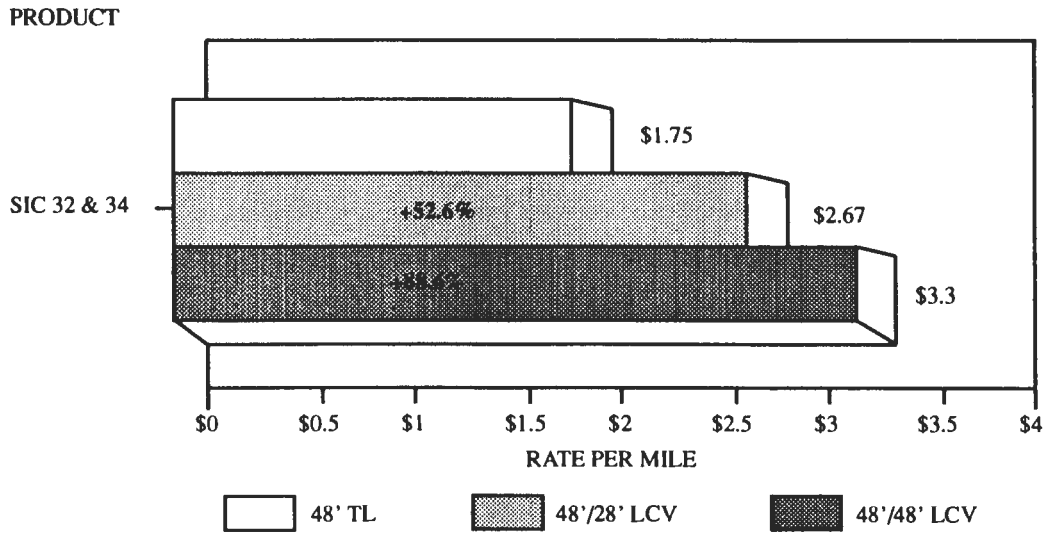

FIGURE 7 Break-even freight rates, Case 3.

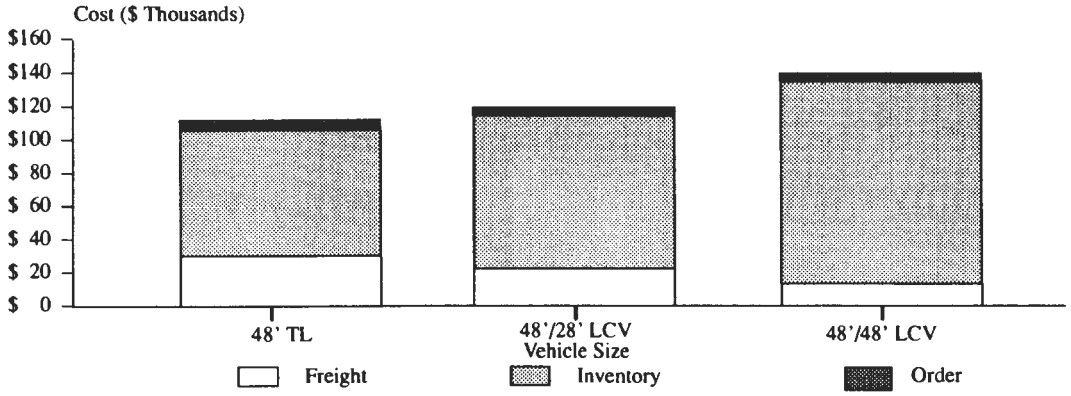

FIGURE 8 Comparison of costs by vehicle size, Case 4.

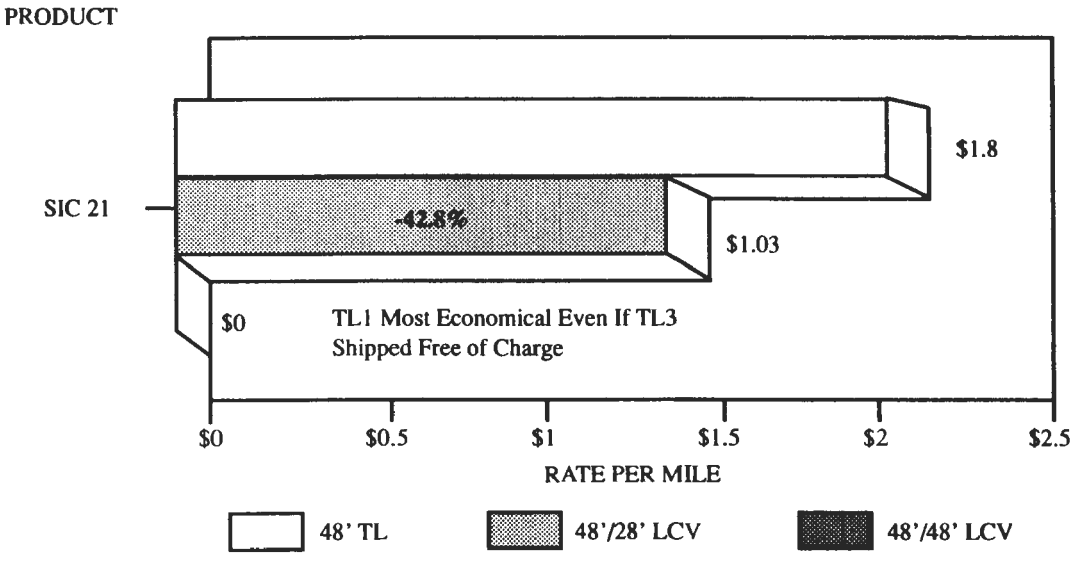

FIGURE 9 Break-even freight rates, Case 4.

As illustrated by these four cases, even with free transportation it is possible to have higher total logistics costs because of the impact of inventory carrying cost when product value is high. Besides inventory carrying costs, other logistics costs can influence the transportation decision because of their impact total cost. Even though the cost (rate) of transportation services is an important variable affecting almost all transportation decisions (maybe the most important factor in some decisions), other costs can offset the effect of lower transportation costs, as we have seen. Shippers are now in a position, as illustrated by the Dow example, to evaluate the logistics impact of varying shipment sizes.

The trends in this society definitely point toward the movement of higher-valued, time-sensitive commodities, which will mean increasing focus on a systems perspective in making transportation decisions (*9*). The next section of this paper will explore some of the most important drivers of change in the U.S. economy that will affect logistics and transportation and the flow of goods and services in the future.

The possibility of increasing customer service while decreasing logistics costs would have appeared impossible in the 1970s, but some major forces were at work during the 1980s that pressured many business organizations to perform more efficiently and effectively and revealed the potential contribution of an underleveraged distribution system.

Drivers of Change

Globalization of Economy and Markets

The internationalization of U.S. companies and the competitive pressure of foreign competition in both domestic and global markets has affected large and small companies. This globalization of U.S. business has been a double-edged sword, providing both a threat and an opportunity. There is no doubt, however, that it is no longer business as usual, and companies have responded in part by copying some foreign business practices, such as just-in-time (JIT) inventory control and flexible manufacturing systems, as well as instituting other changes in their organization structures to remain competitive (*10*).

Globalization runs the gamut from foreign purchasing (sourcing) of raw materials and supplies and selective sales in international markets with extensive use of intermediaries to multifaceted international manufacturing and marketing strategies encompassing international production sites, multistaging inventory, and counter trading product sales. The growing international dimension of both the inbound and outbound logistics channels has had and will continue to have a major impact on the logistics and transportation requirements of companies. The complexity of logistics and transportation will increase because of the length (distance and time) of the distribution pipelines inbound and outbound. The domestic transportation system will have to respond in a coordinated fashion with international transportation companies.

Much of the attention has been directed at the countries of the European Economic Community (EEC) and the Pacific Rim, but the recent signing of the North American Free Trade Agreement (NAFTA) will dramatically change trade relationships with Canada and Mexico (*11*). In fact, much has happened already in terms of trade with Canada and especially Mexico.

Mexico: A Case Study

The trade situation in Mexico provides a convenient example to illustrate the importance and the complexity of global operations for U.S. companies and the transportation service that will be required. The first question to be answered is why Mexico has become important. A few economic variables will answer that question. With about 88 million people, Mexico's population is more than three times that of Canada, but more important, by 1995 more than half of that population will be under 20 years of age—a marked contrast to the U.S. population

(*11*,p.44). This youthful citizenry represents a low-cost labor pool ($12 less per hour than the United States) and a growing consumer market. Mexico's gross national product (GNP) has been growing at 4 percent annually over the past 3 years, and its hyperinflation problem appears to be over. All this combined with a government that has been proactive in attracting foreign investment has made Mexico a very attractive country for foreign producers (*12*).

The most well-known aspect of the proactive governmental policy in Mexico has probably been its Maquiladoras program, which allows companies to set up production and assembly operations and pay duties only on the value added by the additional processing in Mexico. Seventy-five percent of the Fortune 200 companies in the United States have Maquiladoras operations (*13*,pp.32–24). Although Maquiladoras programs tend to be located in border communities, there has been a growth in such operations in interior communities because of the larger population base.

Essentially, the Maquiladoras operation necessitates a transportation movement into and out of Mexico. The international dimension complicates the logistical transportation situation, as indicated by the depiction in Figure 10 of a typical border crossing just into Mexico. The left side of the illustration shows that the number of parties expands to five from the usual one-party operation of a domestic movement. The border clearance charges add between $200 and $400 of additional cost per trailer that does not include the cost of the interior transportation movement. But the labor, utility, and other cost savings offset the additional costs of transportation and logistics (*13*,p.38).

U.S. motor carriers are precluded by Mexican law from operating directly in Mexico—in contrast to Canada. U.S. carriers have responded to the great growth in the flow of products to and from Mexico by establishing alliances with Mexican carriers. J.B. Hunt, Roadway, ABF, United Parcel Service (UPS), Yellow Freight, and others have been aggressive in this area; for instance, the Roadway subsidiary Roadway Bodegas y Consolidacion offers second-day service between Nuevo Laredo and Mexico City and overnight service between Nuevo Laredo and Monterrey. Other examples of such relationships are as follows:

- J. B. Hunt
  - –Established partnership with Santa Fe to move trailers and containers to El Paso,
  - –Moves trailers to border, and
  - –Teamed with Fletes Sotelo, a Mexican TL carrier, to launch Hunt de Mexico to transport within Mexico.
- Contract Freighters Inc.
  - –Signed operating agreements with more than 20 Mexican trucking companies;
  - –Shares customer service, maintenance, and management standards with Mexican partners;
  - –Has terminals in Laredo, El Paso, and Dallas with full-service maintenance, driver residence, and 24-hr dispatch office; and
  - –Averages 900 border crossings a day using more than 3,500 air ride trailers.
- UPS
  - –Runs international express business out of Mexico,
  - –Tests transporter ground business between Mexico and United States, and
  - –Flies own aircraft in and out of Mexico.
- Mexican Express
  - –Is based in Texas;
  - –Introduced less-than-truckload (LTL) capabilities to Mexican partners;
  - –Offers in-bond shipments between Texas and Mexico City, Guadalajara, and Monterrey through subsidiary Transportacion Mexico Express SA de CV; and
  - –Possesses special permit from Mexican government to bring consolidated loads in-bond for customs clearance at destination.

NAFTA also includes tight restrictions on U.S. carriers operating directly into Mexico. This has been a sore point for many U.S. carriers, but change is on the horizon. Alliances with

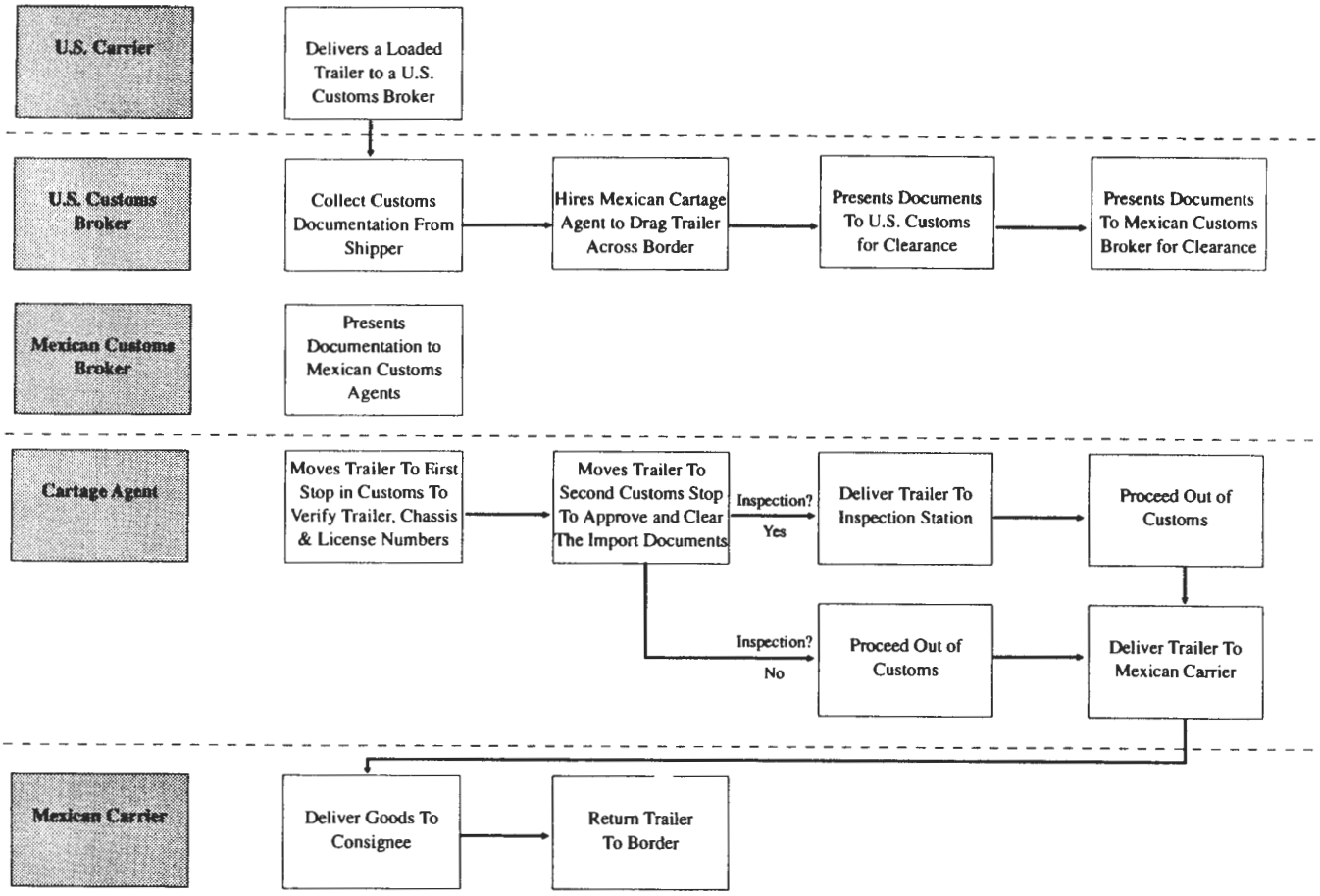

FIGURE 10 Typical border crossing into Mexico.

Mexican carriers have been the only alternative to allow participation in this growing flow of products into Mexico from the United States and back out again. NAFTA will in all likelihood make Mexico even more attractive for manufacturing and processing operations of U.S. companies and necessitate increased alliances, but ownership of Mexican carriers will be possible in several years.

Other Examples

Canada passed a deregulation act in 1988, the National Transportation Act. The act attempted to deregulate transportation, but it required the concurrence of each Canadian province. Ontario deregulated its transportation system in 1989, but Quebec did not. However, Quebec allows progressive market entry procedures. Heavy traffic moves between Canada and the United States via motor carriers. U.S. carriers are allowed to deliver up to 150 mi into Canada, and U.S. motor carriers have a cost advantage over Canadian motor carriers because of the U.S. tax code, which allows investment write-offs not allowed in Canada.

The final economic and financial integration of the Western European countries will establish the largest single market area in the world. The combined gross domestic product will be larger than that of the United States. There will be new distribution patterns internal to the integrated countries and the necessity for international transportation alliances. In fact, many U.S. trucking companies have already moved aggressively to establish partnerships to penetrate the European market.

The EEC's goal of completely eliminating barriers affecting manufacturing and trade will have a significant impact on these countries. The elimination of barriers will increase produc-

tivity by an estimated 5 to 7 percent and could create 2 million to 5 million new jobs. The removal of these barriers will also affect distribution and transportation patterns in Western Europe. Companies currently operating in the EEC need to have plants and warehouses in each of the countries in which they wish to market their goods. With the elimination of trade barriers and tariffs among the various countries, a more regionalized approach, similar to that used in the United States, will be possible. In other words, because countries are very small, a company could have a warehouse in one country from which it will distribute to several countries, using longer, more efficient transportation hauls and larger, more efficient warehouses instead of the current practice of having a warehouse in each country. The regionalized approach is likely to have a dramatic impact in Western Europe and may produce logistics savings not unlike those experienced in the United States during the 1980s (*14*). The potential of Western Europe has also attracted motor carrier companies to form alliances with European carriers.

Globalization has increased the pace of change and will continue to do so throughout the 1990s. Decisions involving sourcing of supplies, manufacturing, assembly, packaging, and warehousing will have a global perspective, and the transportation system will play an important role in linking this all together. Partnerships or alliances of domestic and international carriers will play an increasing role. Intermodal partnerships offer special promise both on a global and domestic basis. Shippers will expect reliable and timely shipments even with the complexity of the global operations. One factor that could help resolve some of the problems of global operations is technology.

Technology

Nowhere in day-to-day business operations is the force of technological change more apparent than in data processing and information systems. Major price breakthroughs in hardware and low-cost, user-friendly software have brought enormously powerful, low-cost computing support to the logistics integration process and to transportation providers.

The impact of changing computer technology on logistical practices has been far reaching. Complex tasks such as truck routing and scheduling are now much more routine when using desktop computers. Simulations of entire logistical systems can be developed to determine the optimal approach to achieving desired customer service performance. It is possible to simulate the knowledge of logistics experts and combine it with current data to develop new strategic alternatives. Such systems offer the promise of linking status and control information from material procurement to delivery of the finished product. The development and management of such a huge data base would not have been possible a few short years ago (*15*).

Currently available systems such as bar coding are being improved and combined with data communication transmission to improve logistical control and manage inventory more effectively. With the advent of satellite transmission, a shipper or carrier can pinpoint the location and schedule of an individual package at any time throughout the entire logistical supply chain. Throughout the logistics infrastructure, carriers, warehouses, and special service providers are introducing much better information and control systems (*16*).

The information transmission part of the technological revolution is worthy of special note. EDI and bar coding have played a major role in the more efficient and effective management of the distribution process, but much more can be done to integrate the systems of vendors, customers, and transportation companies (*15*).

The advances in technology have also spread to other parts of the logistics and distribution system. Automation in warehouses and terminals has advanced at a rapid rate with automated storage and retrieval systems as well as other sophisticated storage and conveyor systems. But perhaps the most important aspect has been the software packages combined with the advances in communication technology to form integrated systems (*17*). We are on the threshold of an era that will revolutionize the way in which business is done because of the advances in technology, and the distribution process will probably be the area of business that is affected the most.

Interestingly, the adoption and use of the current technology is far from universal. Even technologies such as EDI have not been completely integrated into the channels of distribution of some major companies (*18*). The same is also true of some carriers that have not taken full advantage of the available technology. It appears likely that carriers that do not move forward with the available technology will be the business failures of tomorrow.

A dimension of technology that is sometimes overlooked is that it has introduced a form of economies of scale not envisioned previously. Large TL carriers such as Schneider and J. B. Hunt have been able to expand in a market that has been viewed as an analog for the pure or perfectly competitive market model. In other words, such a market would usually preclude a company from becoming larger than its many competitors because of the lack of scale economies. J. B. Hunt and Schneider, as well as others, are examples of the power of technology in providing efficiency in operations; they have provided a basis of efficiency and effectiveness from their size and associated leading-edge technology.

Organizational Restructuring

A third driver of change has been structural changes in business and in the economy, particularly in the United States with changes in both the structure of business and the concentration of markets. Businesses have experienced a series of far-reaching changes with mergers, spin-offs, employee stock ownership plans, and leveraged buyouts, which have created a potential synergy for consolidating logistical operations across newly combined business units (*19*).

No industry segment will probably escape the restructuring and consolidation fever that has characterized business in recent years. Economies of scale, market coverage, and specialization in services and product niches will continue to drive competitors in the worldwide market to make appropriate (or even inappropriate) organizational changes.

A key trend in organizational restructuring has been the flattening or leaning of organizations, with layers of middle management being eliminated and the span of control being increased. The logistics and transportation function has frequently been a primary area for economies to be implemented with less staff. With mergers, one company's department of logistics and transportation is often eliminated; in some instances both company's departments are eliminated and the function is outsourced to a third party in whole or in part. In fact, third-party companies have become so important that they deserve special consideration, which will be provided subsequently. Restructuring continues to be an important agent of change as evidenced by recent events at IBM, General Motors, Westinghouse, General Electric, and other companies.

The outsourcing of logistics and transportation has created a niche for transportation companies to add services that will add value for their customers. Some transportation companies have established subsidiaries to offer broad-based logistical services for their customers, including warehousing, inventory control, order processing, delivery, and so forth (*20*).

The net effect is that transportation companies have changed dramatically and will continue to do so. The alliance or partnerships with other transportation companies, especially intermodal and international relationships as discussed previously, coupled with the third-party opportunities for expanded services has created a new type of organization that is vastly different from the transportation company of the 1970s (*21*).

Deregulation

Another driver has been transportation deregulation, which has spurred a virtual revolution in the U.S. transportation system since 1980, resulting in many fundamental changes, some positive and some negative. Overall, it is probably safe to say that the cost and quality of transportation services have improved for many shippers since 1980. Deregulation started in

1977 with air freight and continued in 1978 with air passenger movements. In 1980 railroads and motor carriers were also deregulated, which was a major political accomplishment.

In all four instances, economic regulation was drastically reduced. In other words, transportation companies became much more like other businesses in being able to adjust their prices and services more quickly in response to the marketplace. Before 1980 a very complex, bureaucratic regulatory system required elaborate hearings to make relatively simple changes in transportation prices and services (22,pp.30–33).

On July 1, 1980, President Carter signed the Motor Carrier Act of 1980. The basic legislation established a federal policy designed to promote a competitive and efficient motor carrier industry that would meet the needs of shippers, receivers, and consumers while allowing price flexibility and encouraging greater efficiency of operation. The legislation offered increased opportunities for new carriers to get into the trucking business and for existing carriers to expand their service (22,p.34) (Figure 11).

The act also made some significant changes in rates. Previously, the motor carrier industry collectively set the rates it charged to the public through the rate bureaus. The 1980 act limited the permissible scope of collective rate making. The net effect has been a substantial lessening of the importance of rate bureaus (6,pp.79–80) in the setting of rates and a significant increase in the volume of independent rate changes.

In the pricing reform area, the act allowed motor carriers and freight forwarders greater freedom to set rates in response to market demands and gave them much more pricing flexibility. Carriers and shippers are allowed to negotiate reduced transportation rates in exchange for a limited liability on the property being transported.

In many ways shippers must now build rate and service protection for themselves where in the past the Interstate Commerce Commission (ICC) acted as a consumer protection agency (6,p.85).

Like the Motor Carrier Deregulation Act, the Staggers Act of 1980 was a mechanism for deregulation of the rail industry. The regulatory structure for railroads was developed over a period of more than 90 years, and regulation has not been completely eliminated. However, the Staggers Act made changes that gave the railroads much more freedom and flexibility to respond to changes in the marketplace. With motor carriers and airlines, the most important

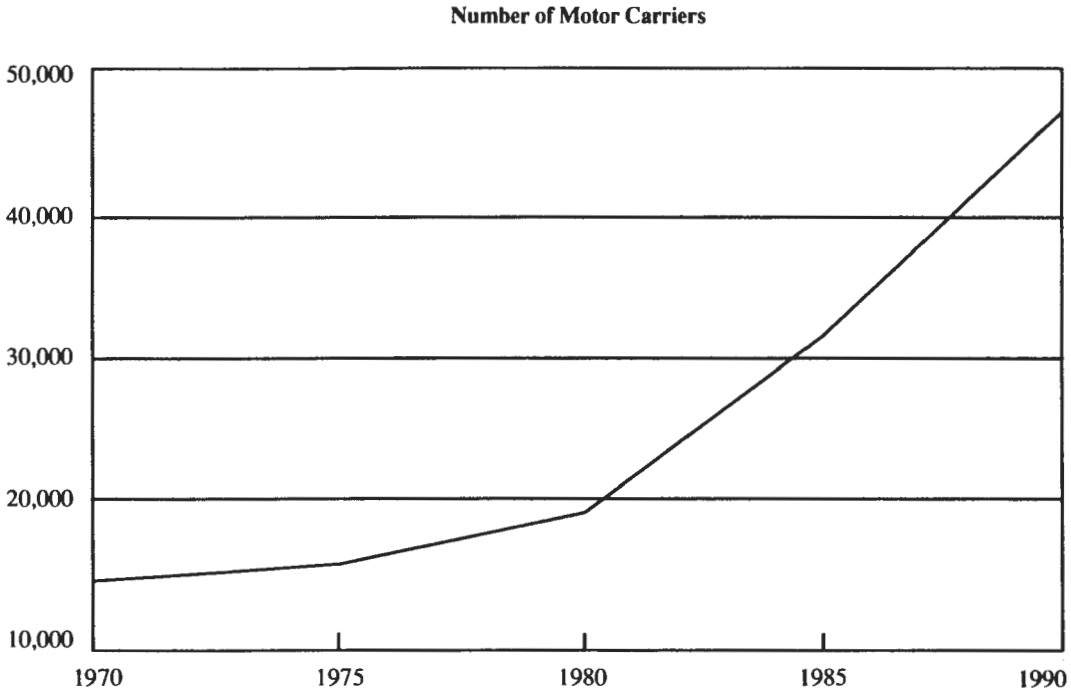

FIGURE 11 ICC-regulated carriers, 1970–1990 (*source: American Trucking Associations and ICC*).

areas of change had to do with entry and exit from service and rate making. For the railroads, rate making was the most important area because the entry and exit issue was so much more complex and long term in nature with the high capital cost associated with entry.

The Staggers Rail Act opened the way for the railroads to start negotiating contract rates with larger shippers, and contract rates have increased dramatically. In 1980, 100 percent of rail traffic was regulated (i.e., the rates were subjected to ICC approval). In 1990, that percentage was below 40—the most dramatic change in any sector of transportation (Figure 12). Railroads and shippers are increasingly cost-conscious in evaluating contract rates. The carriers are looking at the cost of each movement against the revenue gained to eliminate cross subsidization. Some carriers and shippers are putting penalties for delays and premiums for better service into the contracts (*23*,p.12).

Although there has been a significant reduction in economic regulation, there has been an increase in the amount of regulation, control, and policy in other areas, namely, safety and environment. Federal and state controls related to safety and the environment have increased in scope and complexity. The movement of hazardous materials, for example, has received increased attention.

Concerns with gridlock (congestion) and pollution have lead to increasing analysis of approaches to controlling the flow of traffic in urban areas, including required pooling and tolls. The reduction in waste materials and more recycling have also received more attention. Interest is growing among manufacturers in reverse logistics systems to support recycling and waste management. Overall we should see even more legislation and policy related to safety and environment that will affect the design and operation of logistics systems.

The next section will present an analysis of the impact of these drivers of change as reflected in selected distribution and transportation data on a macro level. It is virtually impossible to summarize all changes driven by deregulation. In some cases, the number of carriers has increased dramatically (motor TL carriers); in other instances the number of carriers has decreased (airlines) or there has been a shift toward more market concentration (rail and motor LTL). The distinctions between common, contract, and private carriers have blurred. Transportation companies offer a greater variety of services with a comprehensive set of service and pricing strategies. Transportation companies are vastly different today than they were in 1980, and the pace of change is accelerating. It should also be noted that deregulation in the communication systems and in the financial area has also affected logistics and transportation.

In summary, the four drivers of change—globalization, technology, organizational restructuring, and deregulation—have changed the market and distribution patterns in the United States and the profile of the companies that serve them.

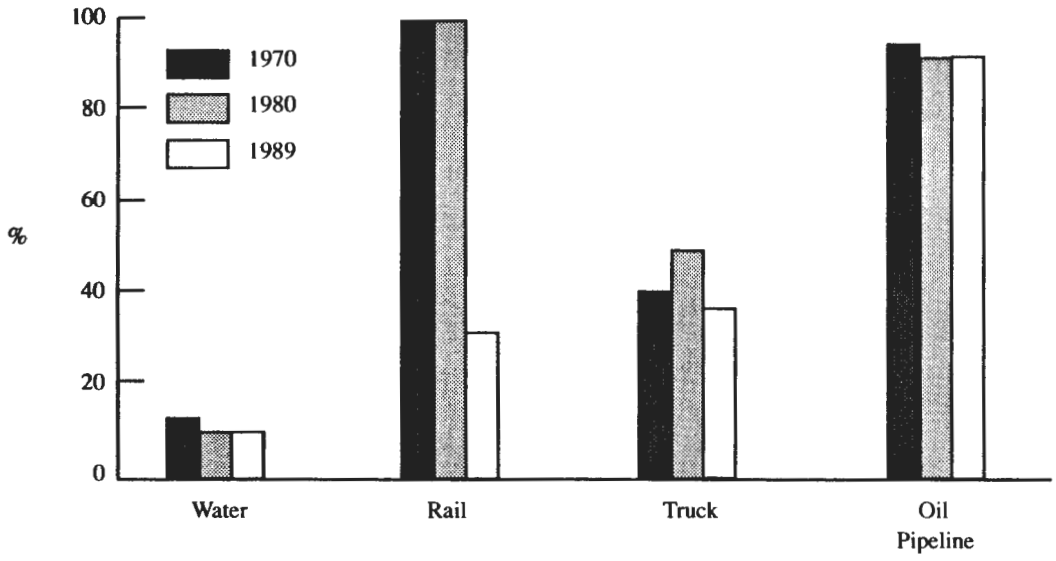

FIGURE 12 Percentage of domestic intercity freight federally regulated by mode.

Discussion and Analysis of Marketplace Changes in Distribution

The logistics-related costs of U.S. businesses should exceed $600 billion/year during the 1990s. Figure 13 summarizes logistics costs from 1980 through 1990, showing logistics costs in billions of dollars and as a percentage of GNP. Aggregate logistics costs have been increasing since about 1983. However, logistics costs as a percentage of GNP declined during the 1980s. The end of the decade showed that logistics costs stabilized at about 11 percent, but this is down from a high near 15 percent in 1981 (*24*).

The projection for the 1990s is that logistics costs as a percentage of GNP will decrease to about 10 percent of GNP. Table 5 presents the components of 1990 logistics costs. As the table indicates, the major categories are inventory costs, transportation costs, shipper-related costs, and administrative costs. The largest, transportation costs, accounted for $277 billion out of $600 billion (*25*). Inventory carrying cost was a close second at $221 billion. Factors that accounted for the relative decline in logistics costs will be discussed subsequently.

Figure 14 compares overall logistics costs, transportation costs, and inventory carrying costs as a percentage of GNP from 1971 through 1989. The top line, which indicates overall cost, shows the previously mentioned logistics costs figure of approximately 11 percent for 1990. The second line shows transportation costs, which during the 1980s declined to about 6.3 percent of GNP from a high of about 8 percent. The third line, which shows inventory cost, also indicates a decline: costs fell to approximately 4 percent from a high of about 6 percent in the early 1980s.

These trends in inventory and transportation costs are quite interesting on a macro basis. Many factors have helped to reduce transportation costs, but one important factor was the deregulation of transportation. That transportation deregulation provided shippers more opportunities to negotiate rates, which led to reduced transportation rates. In addition, increased competition in many sectors of the transportation marketplace also led transportation companies to lower prices. Better transportation service and better inventory management techniques, such as JIT, reduced inventory costs. Overall business logistics costs declined by approximately $65 billion during the 1980s, with about $30 billion in savings from the inventory area and $35 billion in savings from transportation (*25*).

Figure 15 shows the ratio of business inventories to final sales from 1980 through 1989. This is a more dramatic perspective on the relative decrease in inventory. The ratio of inventories to sales was more than 26 percent in 1980, but it declined to less than 20 percent in 1990. This dramatic decrease of inventory levels accounted for $30 billion in savings.

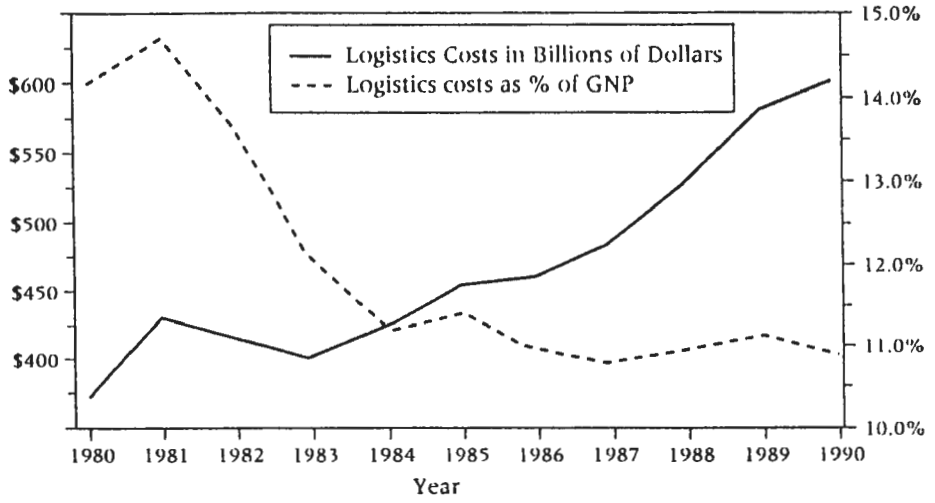

FIGURE 13 U.S. logistics costs, 1980–1990 (*source: Robert D. Delaney, Cass Logistics, Inc.; reprinted with permission*).

TABLE 5 Components of 1990 Logistics Cost

COMPONENT	COST ($ billions)
Inventory Carrying Costs	
Interest	76
Taxes, obsolescence, depreciation	84
Warehousing	61
	221
Transportation Costs	
Motor Carriers	
Public and for hire	77
Private and for own account	87
Local freight services	113
	277
Other Carriers	
Railroads	32
Water carriers	21
Oil pipelines	9
Air carriers	13
	75
Shipper-Related Costs	4
Distribution Administration	23
Total	600

A recent in-depth study of four major industries (chemical, electronics, foods, and pharmaceuticals) shows that they experienced a significant decline in the ratio of inventories to sales ranging from improvements of 23 percent in foods to 37 percent in chemicals, which substantiates the overall data of the Federal Reserve Board (*26*). The data for these four industries are summarized in Figures 16 through 19. These data lend credibility to the macro data in Figure 15. U.S. companies have made a commitment to reduce inventories in the distribution pipeline to gain efficiency. This is true not only in high-valued product industries such as pharmaceuticals but also in such industries as chemicals. The lowering of pipeline inventories as indicated in

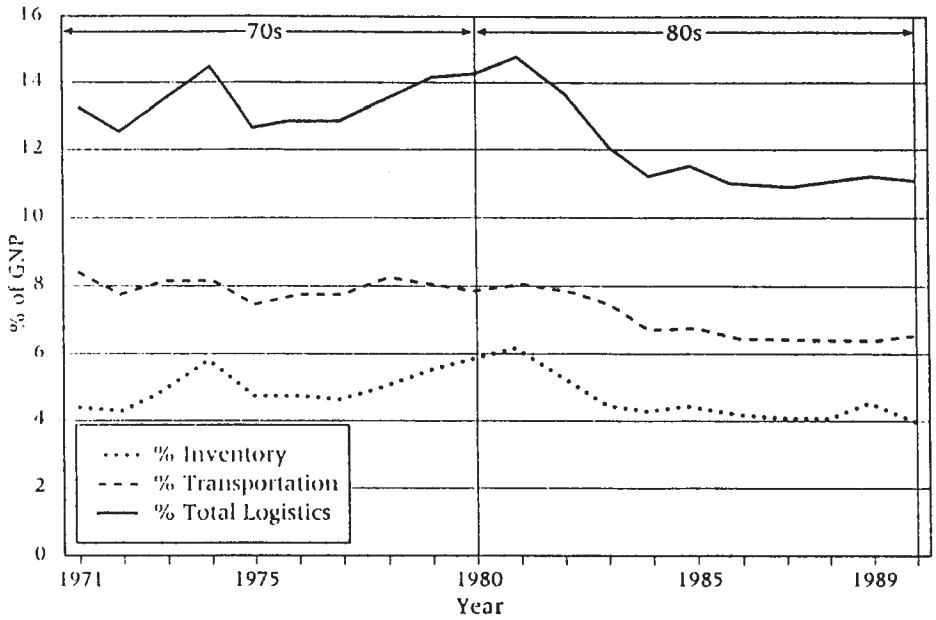

FIGURE 14 Business logistics, transportation, and inventory carrying costs as a percentage of GNP (*source: Robert D. Delaney, Cass Logistics, Inc.; reprinted with permission*).

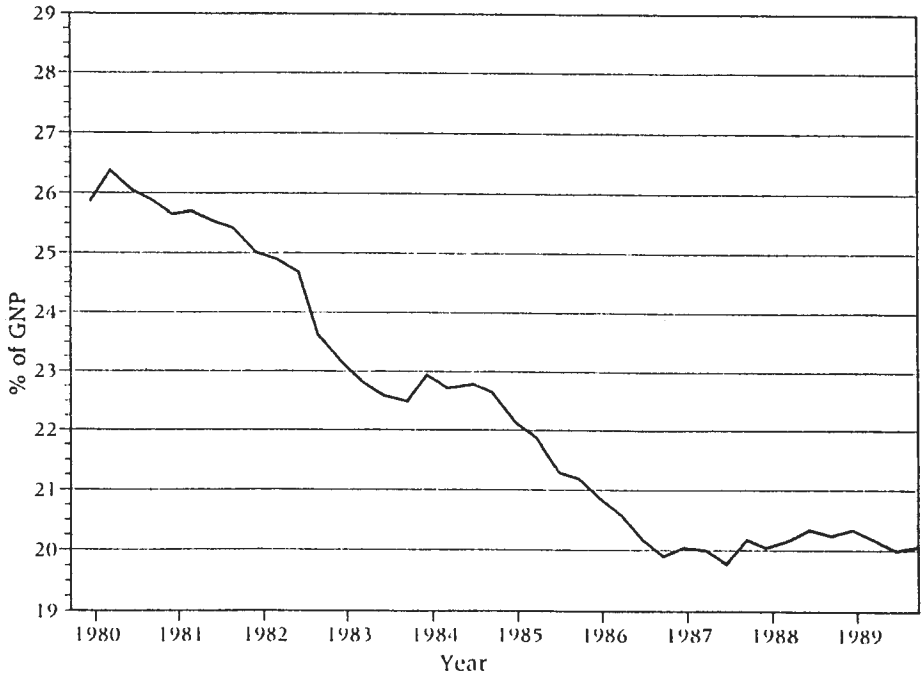

FIGURE 15 Nominal ratio of business inventories to final sales, 1980–1989 (*source: Federal Reserve Board*).

the Dow Chemical example represents a focus point for additional logistics savings during the 1980s. A critical element in the success of such a strategy is a highly dependable, reasonably fast carrier. The motor carrier industry can play an important role in this area, but their service requirements will be particularly sensitive.

Figures 20 and 21 address the transportation costs discussed previously. Figure 20 shows trucking costs during the 1970s and the 1980s using the 1977 constant dollars. This table presents information for both TL and LTL costs, showing that both costs have declined significantly in the post-deregulation era since 1980. The same general conclusion is apparent for railroad costs in Figure 21, which shows costs from 1968 through 1988. Rail costs have been declining since 1980. The reductions in motor carrier costs are more significant than those of railroad. Of the $35 billion combined total mentioned previously, trucking savings accounted for the larger share: $30 billion (27).

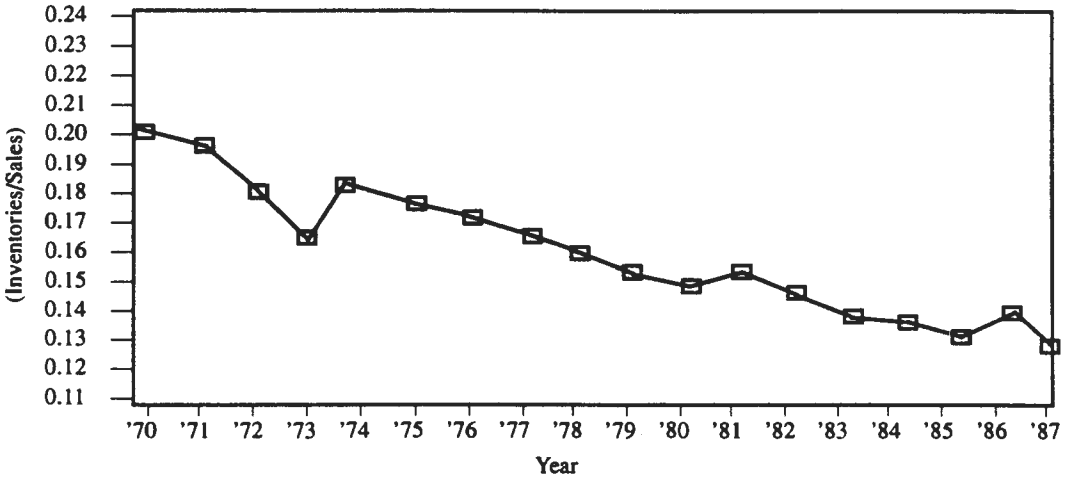

FIGURE 16 Chemical industry, inventories and sales (*36*,p.75).

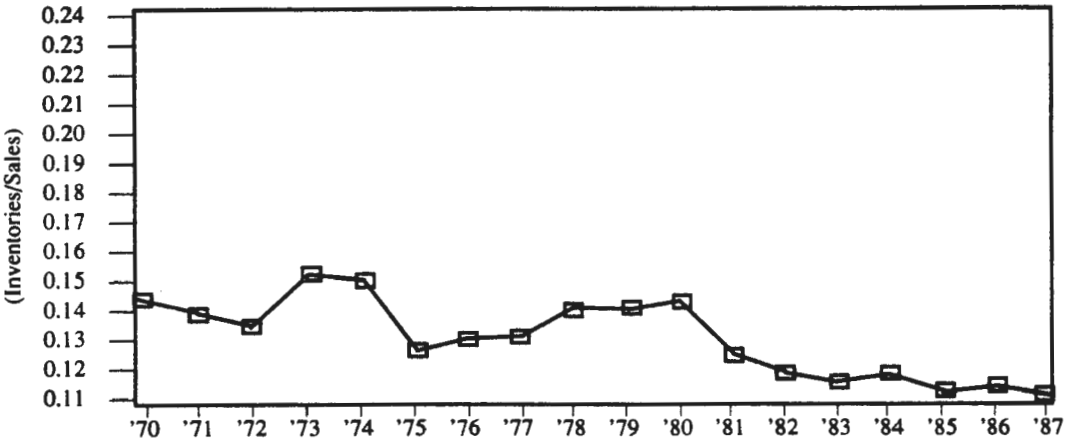

FIGURE 17 Food industry, inventories and sales (*36*,p.80).

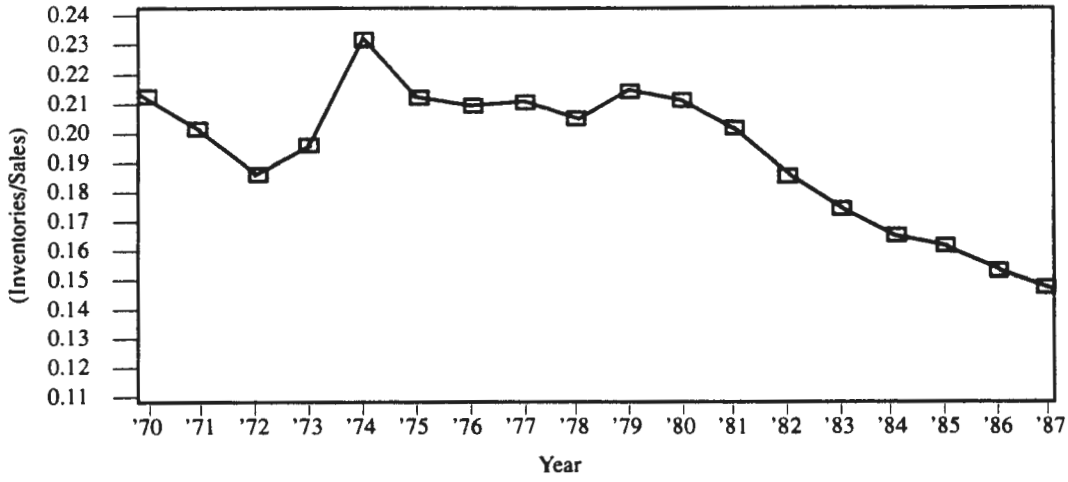

FIGURE 18 Pharmaceutical industry, inventories and sales (*36*,p.81).

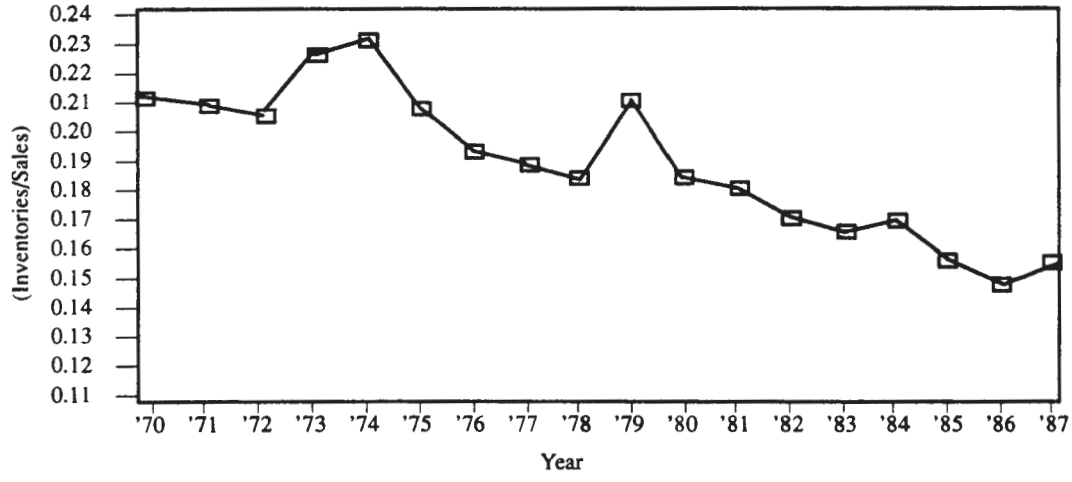

FIGURE 19 Electronics industry, biggest and smallest sales (*36*,p.84).

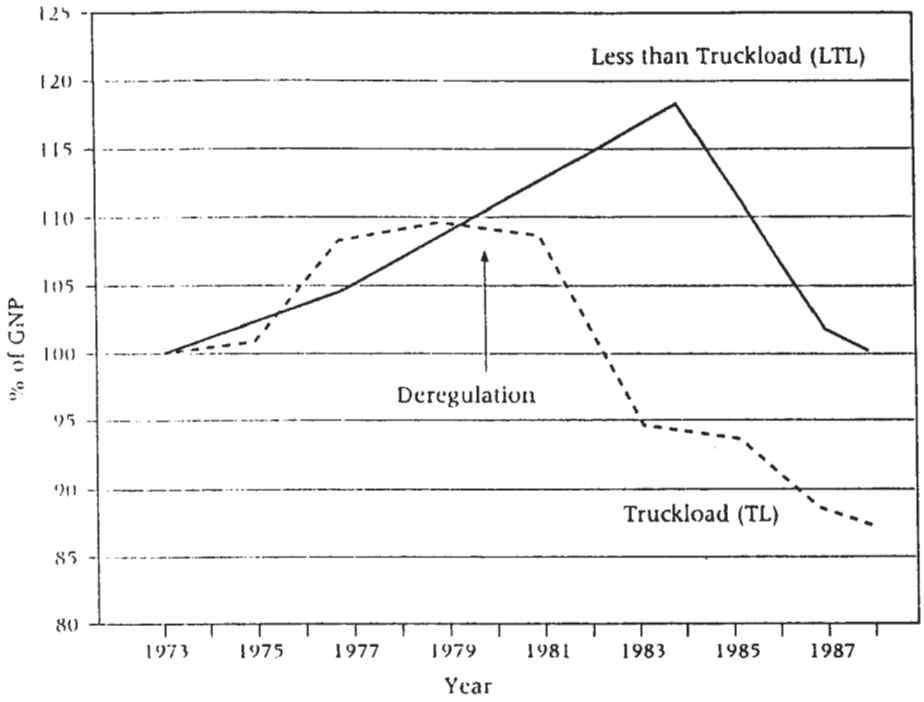

FIGURE 20 Trucking costs, 1973–1987 (*source: Robert D. Delaney, Cass Logistics, Inc.; reprinted with permission*).

The 1990s will see additional savings on a macro basis, and carriers will be under continuing pressure to work with shippers to reduce direct transportation costs or overall logistics costs. One area of particular interest is deregulation of transportation at the state level, which could be a source of important savings. But there are other opportunities to reduce logistics costs, especially pipeline inventories.

On a macro basis, U.S. companies have made significant strides in reducing logistics-related costs during the 1980s, particularly transportation and inventory costs. Deregulation of

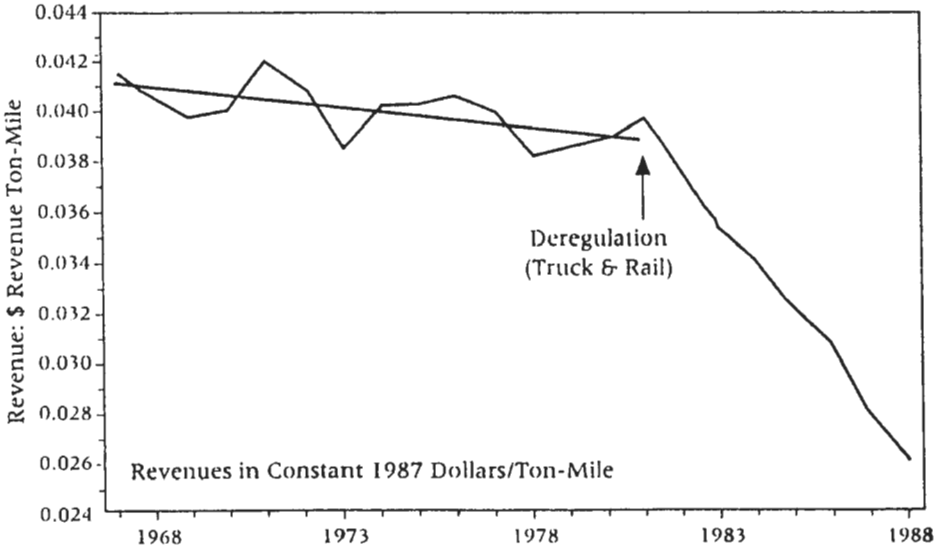

FIGURE 21 Railroad costs, 1968–1988, in 1987 dollars per ton mile (*source: Robert D. Delaney, Cass Logistics, Inc.; reprinted with permission*).

transportation played a major role in providing an opportunity to negotiate rates and service levels which allowed shippers to experience these savings. In addition, improved inventory control approaches such as JIT, DRP, and MRP also allowed more efficiency to be introduced with associated improvements in effectiveness. Better technology, computerization, and automation were also important elements.

Factors Affecting Nature of Demand for Transportation Services in 1990s

In the previous sections, a case has been made for the dynamic marketplace that has significantly affected both carriers and shippers. In many ways, the decade of the 1980s was the decade of greatest change in the history of U.S. transportation. The 1990s will continue the accelerated pace of the 1980s. In fact, the 1990s will probably be a period of even faster change than the 1980s.

Since most of the demand for transportation services (excluding passenger service) is not a primary demand but a derived demand, it is important to understand the factors affecting U.S. business that will in turn influence the nature of the demand for transportation services. The successful carriers in the 1990s will be those that are responsive to the needs and special requirements of U.S. industry. As indicated previously, companies will be affected by global strategies, technology, and regulation. In other words, these factors and others will shape the demand for transportation.

Speed

Most companies have recognized that time is a strategic variable that influences competitive success in the marketplace (*28*). Initially, the focus was on product design and manufacturing to shorten the lead time for the introduction of new models of existing product lines and completely new products. For example, in the automotive industry, the Japanese demonstrated the advantages of shorter, more flexible design and manufacturing strategies that reduced by more than 50 percent the lead time to introduce a new model. Part of Ford Motor Company's resurgence has been based on this same factor.

The emphasis on time compression has spread to other areas, especially the distribution pipeline. Given the current emphasis on reducing inventory levels and JIT, MRP, and DRP inventory practices, transportation will continue to play an increasingly important role in the ability of distribution pipelines to meet the needs of "quick-response" logistics systems. Motor carriers often have an inherent advantage over other surface modes in the area of speed of service, but factors such as congestion and the deteriorating infrastructure will have negative influences. Lower inventories and very short lead times will provide opportunity for airlines to compete with motor carriers for certain products. Federal Express has already demonstrated its competitiveness in selected product markets. Speed will be an area in which companies will seek to lower costs, add value, or both.

Quality

Concurrent with the pressure for reduced lead times has been a significant trend to emphasize quality not only in the production of products but also throughout all areas in a company. The distribution pipeline has again become a major focal point of total quality management (TQM) programs because in the final analysis it is the customer's perceived receipt of quality that is most important. The service areas that interface with the customer, such as transportation, have received increased attention with the recognition of their importance in this area. The expectations of purchasers of transportation services have become increasingly higher in terms of consistent service levels (*23*,pp.10–14).

The synergistic impact of the time compression factor and quality expectations have encouraged carriers to provide service deliveries and pickups to meet increasingly narrow windows—30 to 60 min, for example. The rise in importance of companies such as Federal Express, UPS, Roadway Package Service (RPS), Customized Transportation (CTI), and others is a reflection of this combined trend. But all transportation companies are feeling the impact of this pressure for timely, high-quality, and responsive service (*29*).

The motor carrier has traditionally been viewed as providing the highest overall level of service. It is not the fastest service provider (except for distances under 300 mi), but because of its operating characteristics the motor carrier has usually been able to provide more timely, consistent, and secure service levels than its competitors. The technology advances discussed previously have helped sustain the competitive position of motor carriers, but shippers have emphasized not only sustaining service performance but also continuous improvements (i.e., increasingly better service). The motor carrier industry is in position to respond to the increasingly demanding service levels, but competition from other carriers (rail and air) will intensify (*29*). Motor carriers should investigate how participating in intermodal operations can enable them to lower cost yet sustain quality.

Asset Productivity

Another factor that will shape the demand for transportation service during the 1990s is an increasing concern among shippers about asset productivity. Reducing inventory levels and improving inventory turnover received most of the initial focus of the drive to improve asset productivity as indicated by discussion in a previous section.

Investment in fixed facilities such as warehousing also has been coming under scrutiny, with a definite trend to decrease private warehousing requirements through inventory reductions and increased use of public warehousing. This same focus led to a more stringent evaluation of private motor carrier fleets and a subsequent decrease in the use of private motor carrier operations by many larger companies, especially for intercity movements (*30*).

The drive to improve asset productivity has focused on reducing not only internal inventories but also pipeline or supply chain inventories. Vendors and buyers have been cooperating and sharing data in an attempt to reduce inventories in the entire distribution pipeline. Procter and Gamble (P&G) and Wal-Mart have received much attention in the business press for their efforts in this area, but there are many other examples (*31*). Again, fast, responsive and flexible transportation becomes a critical part of this vendor-customer relationship.

Organizational Reengineering

Another trend among U.S. corporations is the reexamination and evaluation of the internal processes to minimize transactional activities and emphasize value-adding activities. A manifestation of the reengineering has been the reduction of middle management in many companies (*15*,pp.10–13). An outcome of the thinning of middle management ranks has been a trend toward outsourcing of distribution activities to focus more on core activities that add value. The development of third-party companies that provide a range of distribution and logistics services on a contract basis to companies has been a response to such changes. A growing number of transportation companies, including motor carriers, have established third-party logistics companies that offer a range of logistics services including transportation (intercity and cartage), inventory management, warehousing, order processing, billing, and more. Some trucking companies have established third-party organizations that offer services to a broad base of users; others have emphasized a particular niche such as the automotive industry (e.g., CTI of Jacksonville, Florida).

Another dimension of the changing organizational relationships that is important to transportation demand is the practice adopted by shippers of reducing the number of carriers from which they buy transportation service to leverage their buying power (*32*). This practice is an

outgrowth of deregulation and is also associated with the JIT philosophy of operations that stresses "win-win" buyer-seller relations based on long-term, high-volume, quality-based vendor commitments. The decrease in the number of carriers used by individual shippers has been dramatic: some have gone from more than 1,000 to fewer than 100 carriers. Such relationships are viewed as partnerships not unlike the relationship between P&G and Wal-Mart, in which shippers and carriers share information that allows a win-win opportunity: lower rates and improved carrier efficiency.

Customer Satisfaction

Another trend among shippers that is affecting the demand for transportation is the customer service—customer satisfaction emphasis, which is particularly important to logistics and transportation (*33*,pp.257–272). It has long been recognized that measures of service levels are important to evaluate performance. Traditional measures included the length of the order-delivery cycle, order shipment time, and orders shipped complete. Now measures are aimed directly at the customer side. For example, the very best companies use measures such as on-time delivery, orders received complete (no loss and damage), and orders billed accurately. One result of the customer service focus is that transportation services receive more attention and transportation companies are frequently viewed as partners in providing the higher levels of customer service (*33*,pp.258–260). This has often necessitated data sharing between shippers and carriers to develop the win-win type of relationship mentioned earlier.

Another aspect of the customer satisfaction focus is the levels of customer service delineated by the very best companies. Reliability is viewed as the basic requirement with the added level of flexibility to meet special needs of customers. The icing on the cake is the addition of creativity to add value that will affect the customer's bottom line. Again, transportation can and will play an important role in this new era of customer service. Perhaps a better way to state the case is that the successful carriers will be those that can offer customized and tailored services to be responsive to needs of shippers who will be required to offer excellent service to maintain a competitive position in today's marketplace (*33*,pp.265–270).

In summary, the nature of the demand for transportation services in the 1990s will be different and will be shaped by the marketplace factors discussed in this section. The view of transportation as the simple movement of goods through space from origin to destination is not enough. Transportation companies must be much more sophisticated in developing services to meet the needs of shippers. The logistics perspective outlined previously is a necessary concept for carriers to understand. But the demand for this better service will not soften the pressure to provide such service at a low cost.

By using a much smaller carrier base from which to purchase transportation service, large shippers will change the demand for services dramatically. Low cost (efficiency) will be an expectation, but the ability to provide high-quality service (effectiveness) will become the critical factor. Projections based completely on historical data will therefore have reduced significance in the 1990s environment. Shippers will expect a seamless pipeline that is responsive and flexible.

Summary and Conclusions

The evidence continues to grow indicating dramatic improvement in productivity associated with the logistics costs, including transportation, of U.S. businesses. In fact, 1991 was a year in which overall logistics costs were lower absolutely and relatively (see Figure 22). The savings in 1991 can again be attributed to lower investment in inventory, lower interest costs, and continued control of warehousing and inventory cost (6,p.7).

The lower inventory costs can be attributed to better logistics management along with better transportation service. The increased reliability and flexibility of carriers has enabled man-

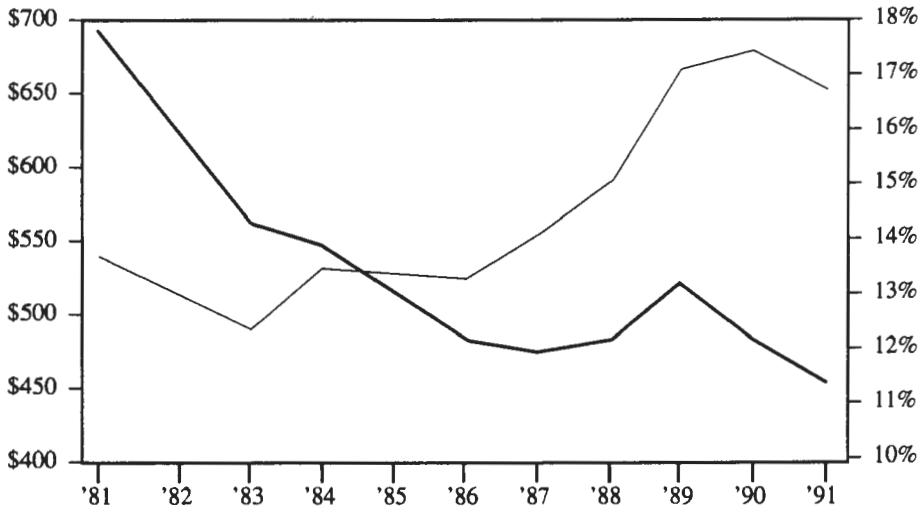

FIGURE 22 Logistics cost in relation to gross domestic product (*source: U.S. Department of Commerce*).

agers to reduce safety stock levels and to reduce the number of inventory stocking points.

In the 1980s, savings of more than $65 billion associated with logistics contributed to overall productivity improvements in many companies and helped to make U.S. business more competitive on an international basis. Manufacturers and other companies are shipping heavier loads, using lighter packaging materials, and reducing empty vehicle miles.

Motor carrier transportation continues to play a major role in our economy, and by two measures—total tonnage and freight revenue—is the most important mode of transportation. In fact, motor carriers have improved their position by both measures during the 1980s, when their revenue went from 74 percent of total transportation revenue to 78 percent and tonnage went from 36 percent to 41 percent. Only in the area of ton miles carried, which reflects both tons and miles, were railroads larger. But interestingly, rail ton miles stayed basically constant during the 1980s (37.5 to 37.6 percent), and motor carrier ton miles grew from about 22 to 25.6 percent of total (27).

Motor carriers have fared reasonably well with the increased emphasis on the integrated logistics approach in which efficiency and effectiveness are important. Motor carriers will need to continue their aggressive response to shipper requirements to be successful in the 1990s. We will see more value-added services and intermodal cooperation to achieve these goals. The infrastructure, environment, increased fuel taxes, safety, and other issues will challenge the motor carrier industry and influence the demand for and supply of transportation.

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Motor Carrier Industry Structure and Operations

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A prominent transportation analyst recently concluded, "Here we are twelve years after the motor carrier industry was deregulated in 1980 and the pace of change, if anything, has accelerated. It's been a very exciting industry to be involved in. Change continues at a very rapid pace and I have the feeling that it may continue for another 10 to 12 years" (*1*,p.27).

It is the objective of this paper to review the changes that have occurred in both the less-than-truckload (LTL) and truckload (TL) segments of the motor carrier industry. It is the goal of this paper to provide an understanding of the structure of these segments of the motor carrier industry and the operations of the firms in each of the two segments. The analysis will explain some of the very significant changes that have occurred in an industry adapting to radical change in the governing rules. There will be clear evidence of winners and losers as different carriers have adopted different strategies to cope with the new environment. The major underlying conclusion is that the motor carrier industry in 1993 is delivering a service that is of significantly higher quality and greater efficiency than it was in the regulated environment.

LTL Industry Segment

Overview

The transition from a highly regulated and controlled market to a substantially more competitive one has resulted in vast changes in the LTL segment of the industry. That segment has witnessed a tremendous shakeout in the number of its competitors as well as in the concentration of business among the largest firms. Despite this increased concentration, there are clear signs that competitive forces are exerting a strong influence on the marketplace, as anticipated by proponents of deregulation. During the transition period, the industry has significantly lowered its costs, primarily through substantial decreases in labor costs combined with notable efficiency improvements. At the same time, prices in the LTL segment have been lowered even farther than costs have been reduced. As a consequence, overall profitability in the LTL segment is down. Adding to their woes, LTL firms are facing new competitive forces outside their own industry segment that were substantially less significant in the regulated era.

To meet the new market conditions, firms have had to devise strategies that are distinctly different from the ones that worked well in the regulated environment. Firms can be differentiated on the basis of their ability to adapt to the new circumstances. Those that are most clever reap significant benefits; those not adapting or selecting ineffective strategies have failed. Indeed, there is strong evidence that individual firms can perform profitability in the new environment if their strategic response has been altered to reflect the new market forces.

Although some evidence indicates that firm size provides some advantages to carriers in a deregulated environment, econometric studies continue to show that there are no significant economies of scale among the LTL carriers. Indeed, some of the most profitable LTL carriers in this environment have been regional carriers with operating revenues substantially lower than those of the national carriers. As a consequence, the observed increases in industry concentration should not alarm policy makers or signal the need to reverse the forces of deregulation.

This section will document the changes experienced by carriers in the LTL segment as outlined in the preceding paragraphs. The discussion will conclude with a presentation of the range of strategies being devised to take LTL firms into the 1990s and beyond. Some of these strategies have expanded the traditional LTL firms into new and innovative business lines.

Increased Concentration and Reduced Number of Firms

For this discussion, the LTL segment of the motor carrier industry refers to "Instruction 27" carriers—that is, those carriers that derived an average of 75 percent or more of their revenues during the 3 previous calendar years from the interstate transportation of general freight. The primary activity of carriers in this group is to handle LTL quantities of freight. A few carriers in the Instruction 27 group handle very little LTL freight, but for purposes of comparison across years and with previous studies, the benefits of a constant carrier frame as provided by the Instruction 27 group were thought to outweigh the disadvantages associated with including a small number of carriers that might fit better in another category.

Figures 1 through 4 are based on an analysis of the Instruction 27 carrier data given in annual reports filed by Class 1 and 2 carriers to the Interstate Commerce Commission (ICC) (2). The annual report data were processed from the American Trucking Associations' computer tapes covering 1976 through 1989. Figures 1 through 4 demonstrate two salient points about the transition from regulation to deregulation: the LTL industry witnessed a substantial increase in market share among the largest of the carriers as well as a significant decrease in the number of competitors.

Figure 1 measures changes in the concentration of total revenues among firms in the LTL industry segment. In 1976 the top three firms in this segment accounted for 14 percent of total revenues, the top four firms for 17 percent, and the top eight firms for 24 percent; by 1980 these figures had increased to 18, 21, and 32 percent, respectively. The concentration of the revenues of the LTL firms among the top firms increased gradually through the deregulated years, as shown in Figure 1. By 1989 the top three firms garnered 35 percent of the segment's total revenues, the top four accounted for 40 percent, and the top eight were responsible for 52 percent.

Figure 2 also demonstrates a significant increase in concentration among the LTL carriers when ton miles are used as the concentration measure. In 1980 the top three firms had 20 percent of the segment's total ton miles, the top four had 25 percent, and the top eight had 38 percent. These numbers changed drastically during deregulation so that by 1989 they were 35, 43, and 57 percent, respectively. Figure 3 also presents convincing evidence of a sizable increase in concentration when operating assets of the LTL firms are used for the concentration measure.

The increase in the concentration of business among the segment's largest firms has been combined with a substantial decrease in the number of competitors. Figure 4 shows that in 1976 there were 614 Class 1 and 2 carriers in the LTL industry segment. Class 1 carriers are defined as those with revenues in excess of $5.78 million, and Class 2 carriers are those with

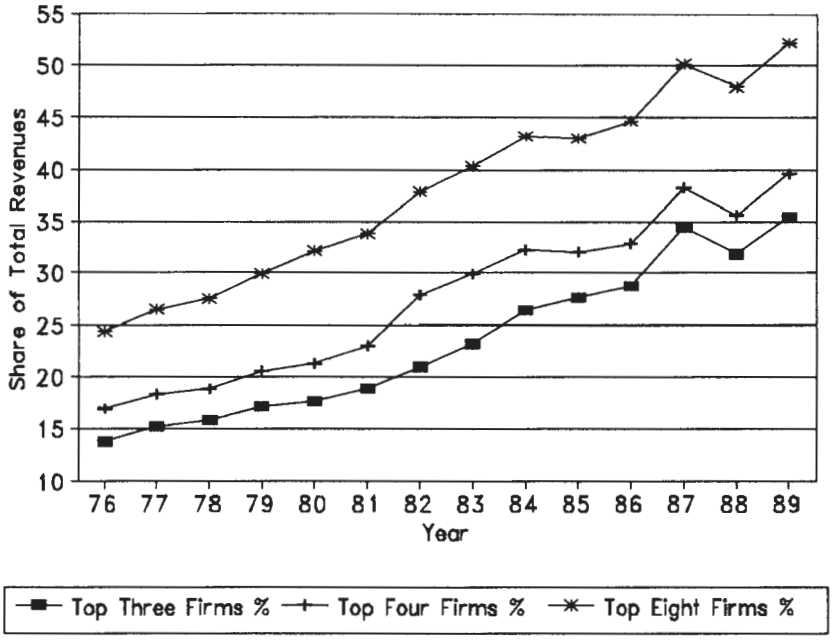

FIGURE 1 Concentration in LTL revenues.

revenues in excess of $1.16 million. By 1980 the number of Class 1 and 2 carriers had fallen to 498. The number of carriers has decreased under deregulation to 326 in 1984, 273 in 1987, and 237 in 1989. Thus by 1989 the number of Class 1 and 2 LTL carriers had fallen by more than 60 percent. The many Class 3 carriers that entered the marketplace after the Motor Carrier Act of 1980 were almost exclusively in the TL industry segment. Thus the decline in the number of Class 1 and 2 LTL carriers represents an absolute decline in the total number of carriers in the LTL segment.

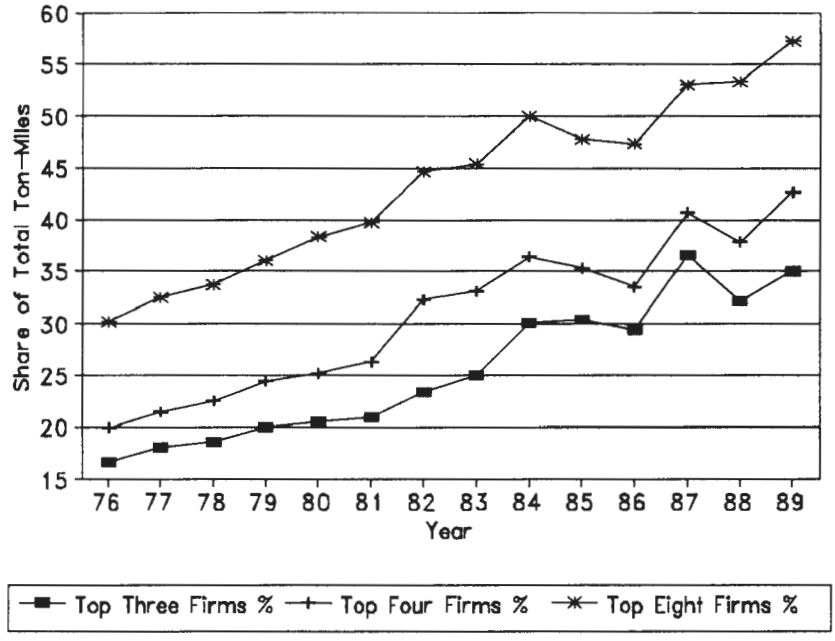

FIGURE 2 Concentration in LTL ton miles.

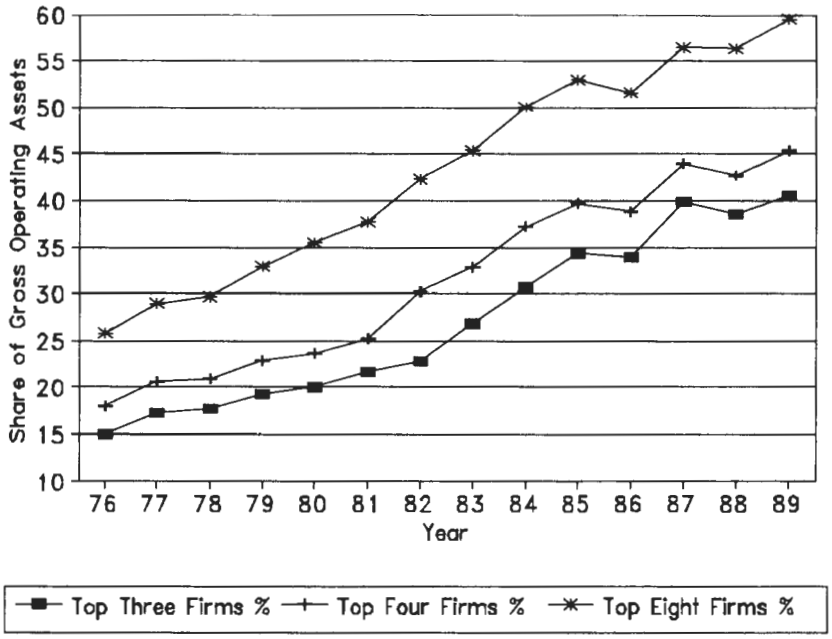

FIGURE 3 Concentration in LTL operating assets.

Cost Reductions, Productivity Improvements, and Price Reductions

Table 1 gives information on differences in costs between 1977 and 1987 for all LTL firms grouped together. The basic message in Table 1 is that the LTL firms significantly reduced their per-mile operating costs during the transition from regulation to substantial deregulation. The cost categories shown in Table 1 include the following on a per-mile basis: total operating expenses, employee compensation, fuel, operating licenses and taxes, purchased transporta-

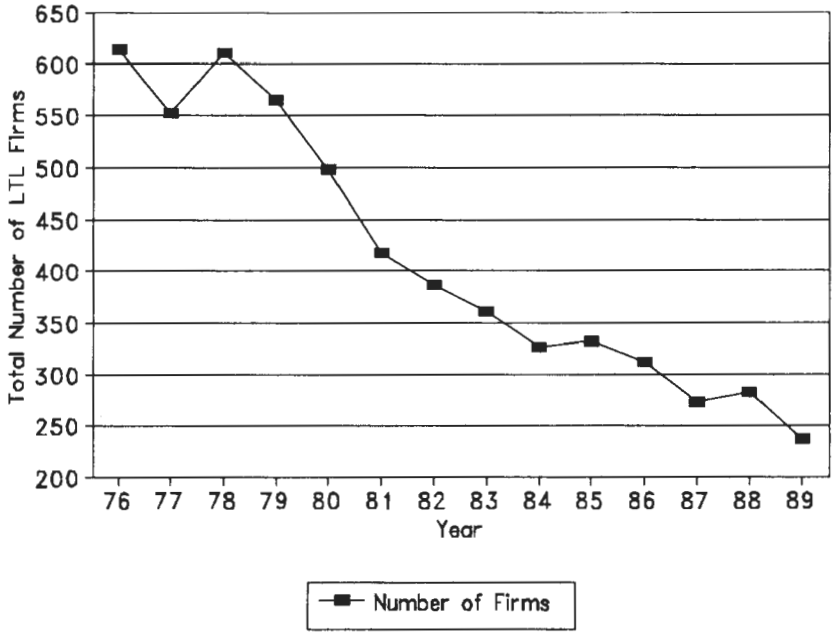

FIGURE 4 Concentration in number of LTL firms.

TABLE 1 LTL Costs Before and After Motor Carrier Act of 1980 ($ 1987) (3)

Carrier Expense Category	1977 ($)	1987 ($)	*T*-Ratio
Operating expense (per mile)	4.10	3.01	7.72*
Compensation (per mile)	2.28	1.42	9.00*
Fuel expense (per mile)	0.23	0.17	7.99*
Operating license (per mile)	0.23	0.11	3.83*
Purchased transportation (per mile)	0.34	0.39	1.19
Maintenance (per mile)	0.07	0.05	2.92*
Compensation (per employee)	35,500	28,500	4.20*
Line-haul expense (per mile)	1.13	0.93	3.75*

NOTE: * = statistically significant difference at .01 level.

tion, and maintenance. Total operating expenses are the sum of these individual categories in addition to a miscellaneous category not shown in Table 1. Also included in Table 1 are data on the average compensation per employee. [This section of the paper draws heavily on the article by Corsi and Stowers (3).]

As shown, the LTL carriers experienced a decline in operating expenses per mile of 27 percent, from an average of $4.10 in 1977 to $3.01 in 1987 (measured in constant 1987 dollars). The largest source of this overall decline is attributed to decreases in employee compensation per mile. Indeed, measured in constant 1987 dollars, per-mile employee compensation decreased from $2.28 in 1977 to $1.42 in 1987. Table 2, focusing on the sources of the observed reductions in real per-mile operating expenses, indicates that the employee compensation expense category accounts for 79 percent of the overall decline in per-mile expenses during the transition. Indeed, the average employee compensation in constant 1987 dollars decreased 19.7 percent, from $35,500 in 1977 to $28,500 in 1987.

The LTL carriers also experienced real declines in several other important expense categories: fuel and operating licenses and taxes; maintenance; and miscellaneous. Fuel expenses per mile for the LTL carriers decreased in real terms from 23 cents in 1977 to only 17 cents in 1987. This savings, combined with a decrease of 2 cents per mile in the real cost of operating licenses and taxes, resulted in a decrease of 8 cents per mile in real operating expense during the 1977 to

TABLE 2 Sources of Reduction in Real Operating Expenses per Mile, LTL Carriers (3,p.16)

Source of Operating Expense Decline	Real Decline ($)	Percentage
Overall	1.09	100
Employee compensation	0.86	79
Fuel and taxes	0.08	7
Maintenance	0.02	2
Purchased transportation	+0.05	+5
Other	0.18	17

NOTE: All figures in the table are declines except those with plus sign.

1987 period. These two categories combined represent 7 percent of the total real decline in operating expenses per mile.

Among the LTL carriers, the per-mile maintenance expenses in constant 1987 dollars decreased from 7 to 5 cents, a significant decrease that accounts for 2 percent of the overall reduction in real operating expenses per mile. This reduction most likely reflects the introduction of newer-model trucks with engineering and design improvements that necessitate fewer expenditures on routine maintenance.

Some of the real per-mile cost reductions observed for the LTL segment were a direct result of various productivity improvements from 1977 through 1987. Indeed, per-mile cost reductions stem from either direct cost reductions or increases in the vehicle mile output for a given level of input. In addition to the previously documented cost reductions, there is direct evidence that carriers in the LTL segment improved their productivity. Indeed, the average vehicle miles per power unit increased by 32 percent between 1977 and 1987, from 37,200 to 49,200 mi. Furthermore, the average length of haul increased from 211 to 313 mi between 1977 and 1987. This represents a statistically significant increase of 48 percent. This increase in length of haul represents the consequence of reduced entry control, which allowed the LTL carriers to expand their geographic territories and provide service to a wider geographic area without the need to interline.

The LTL carriers greatly cut their operating expenses per mile, primarily through substantial cost reductions (especially in the area of employee compensation) and improved operating efficiencies. The resulting reduced costs were passed on to the consumers in the form of lower prices. The operating revenue per mile for the LTL carriers in constant 1987 dollars decreased from $4.25 in 1977 to $3.06 in 1987, a decrease of 28 percent. Thus, among the LTL carriers the reductions in revenue slightly outpaced the reductions in cost.

Indeed, the experience of the LTL carriers during the transition to deregulation provides no evidence of monopoly exploitation of market advantages. Thus, despite the evidence of significant concentration increases, the marketplace is working effectively to bring about significant efficiency enhancements that are being fully passed onto the consumer in the form of lower prices.

Reduced Profitability and New Sources of Competition

Confirming the finding that revenues decreased at a faster pace than did costs, the following table shows that the LTL firms collectively experienced a decline in profitability during the transition from regulation to substantial deregulation (*3*,p.22):

Profitability Measures	*1977*	*1987*	*T-Ratio*
Operating ratio	96.1	98.5	4.79*
Net income/operating revenue	2.7	1.0	5.10*
Net operating income/assets	9.2	3.0	5.61*

(The asterisks show a statistically significant difference at .01.) As indicated, the average operating ratio of the LTL firms in 1977 was 96.1 percent. This figure worsened significantly to a level of 98.5 percent in 1987. Other profitability measures (i.e., net income/operating revenue or net operating income/total assets) also show significant worsening between 1977 and 1987. Net income as a percentage of operating revenue decreased from 2.7 percent on average in 1977 to 1 percent in 1987. Similarly, net operating income as a percent of total assets declined from 9.2 percent on average in 1977 to a level of 3 percent in 1987. Clearly, on average, LTL firms suffered significant profit losses as a consequence of deregulation.

The finding of profitability losses among the LTL firms is consistent with other analyses of the impacts of the regulatory change (*4*) and was anticipated by the proponents of the Motor

Carrier Act of 1980 (*5*). As will be outlined in the following section, however, it would be wrong to assume that the "overall" profitability malaise was shared equally by all LTL firms.

In addition to substantial overall profitability declines, the LTL carriers faced sizable new competitive forces, outside the domain of the LTL carriers, during the transition period. These new forces, weak or nonexistent before the move toward a deregulated transportation market, grew much faster than did the LTL carriers during the transition.

The impact of the new sources of competition on the LTL carriers is shown in Figures 5 through 7 (*36*,p.55). Figure 5 indicates that the total size of the LTL market (in terms of total operating revenues) increased from slightly more than $11 billion in 1976 to about $17 billion in 1989. However, Figure 6 demonstrates that during this same period, LTL carriers experienced competition in the "small-shipments" markets from a variety of additional competitors. Indeed, during the transition period, United Parcel Service (UPS) (not including its air package operations) and the air carriers substantially increased their participation in the small-shipments market.

In 1976 LTL carriers controlled about 80 percent of the total small-shipments market of about $15 billion (Figures 6 and 7). However, during the 1980s LTL carriers saw their share of the small-shipments market decrease so much that by 1989 they controlled less than half of the total market. Indeed, the total small-shipments market increased from slightly less than $15 billion in 1976 to $35 billion in 1989—an increase of 133 percent. This compares with an increase during the same time in the total revenues of LTL carriers of only 55 percent.

LTL firms made important inroads in their market dominance from UPS and the air carriers. UPS experienced an increase in its share of the small-shipments market from 10 to almost 30 percent between 1976 and 1989. Air carrier small shipments increased from about 8 percent of the total market in 1976 to approximately 22 percent in 1989.

Thus, the LTL firms overall suffered significant profitability losses during the move to deregulation and a deterioration in their dominance of the small-shipments market as both UPS and air carriers outpaced the LTL firms in terms of market growth. It is certainly an understatement to suggest that the transition to deregulation for the LTL firms, in general, was very difficult.

The LTL carriers also suffered losses in market share for the TL business that they used primarily as back-haul traffic in the regulated years. Many LTL carriers cited loss of TL traffic as a major problem during the early years of transition to a deregulated marketplace. The TL

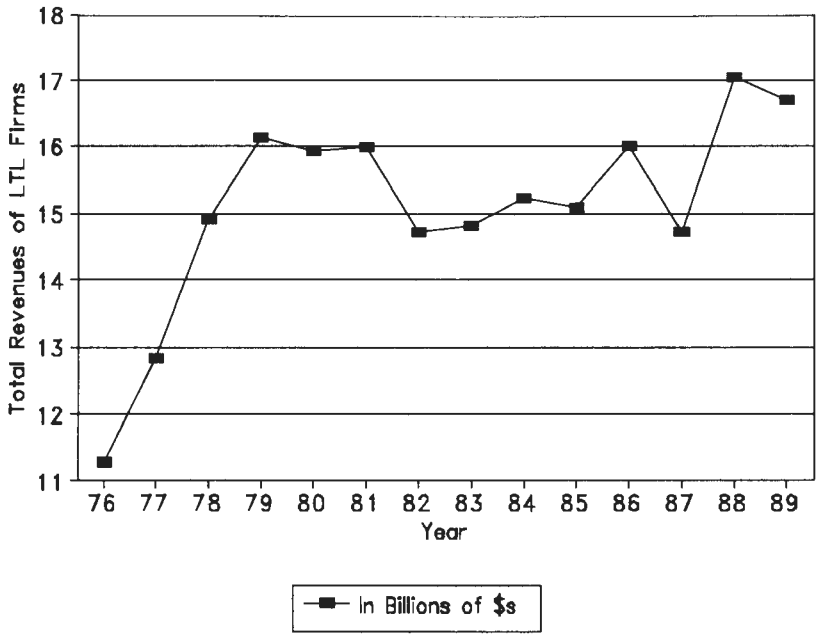

FIGURE 5 Size of LTL market in total revenues.

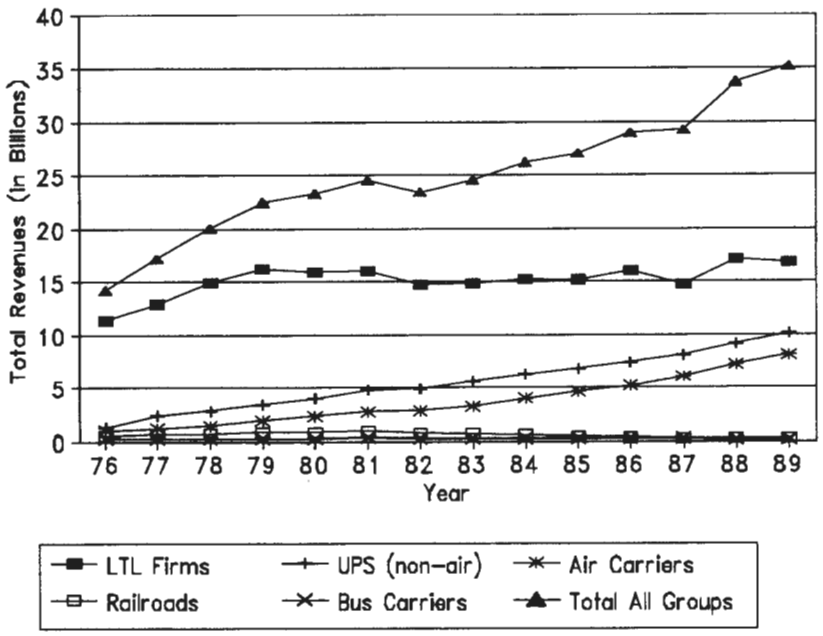

FIGURE 6 Market size, LTL firms and their competitors.

carriers had a lower cost structure than did the LTL carriers and were able to take the back-haul TL traffic of the LTL carriers through aggressive pricing. Between 1977 and 1987, the TL business that the LTL carriers had enjoyed under regulation virtually disappeared.

Management's Strategic Response

The Motor Carrier Act of 1980 identified the enhancement of market competition in the industry as one of its primary objectives. It was anticipated that such an environment would

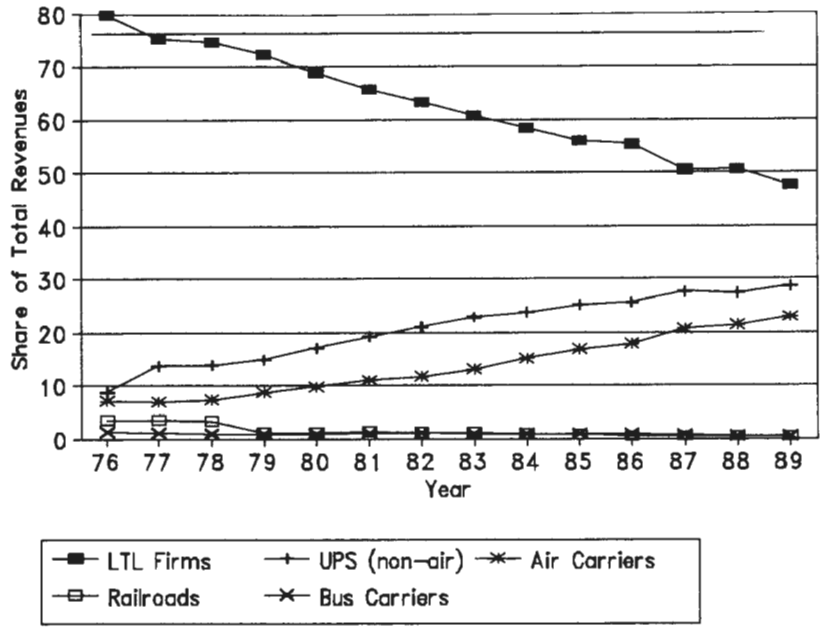

FIGURE 7 Market share, LTL firms and their competitors.

challenge motor carrier managers to increase the efficiency of their operations and would allow the more innovative ones to gain marketplace rewards. Scholars of strategic management would expect that a major environmental change, such as the move to substantial deregulation, would dictate a need for firms to alter their strategic focus in order to cope with the new circumstances.

Implicit in these assumptions is that some motor carrier managers would not recognize the need to alter strategies to fit the new environment. Other managers would set off on a course inappropriate for the changed environment. In both cases, specific managerial decisions would start the firms down a course leading ultimately to bankruptcy. The new market environment does not protect the managers from the consequences of their decisions. It is, thus, not surprising that many LTL firms went bankrupt during the years of transition to a competitive market.

A recent investigation of strategic change in the LTL segment during the transition documented many of these beliefs (*7,8*). The study found that in a regulated environment, there was no statistically significant difference in performance across the LTL firms grouped according to the strategic focus of the firm. Regulation provided the LTL carriers with a very protected environment that shielded them from both rate competition (through highly effective government-sanctioned rate cartels) and new entry (through highly restrictive entry procedures). Given these protections, it is plausible that firms placed low priority on identifying their strategic missions. Certainly, performance in this environment was not related to firm strategy.

The study found, however, that in the deregulated environment there were notable performance differences across the firms grouped by identified strategic focus. In the competitive environment, certain strategies appeared to work quite well while others worked much worse. Firms pursuing a strategy of differentiation realized a level of performance far higher than that of the rest of the firms. In contrast, firms pursuing a low-cost or broad product and geographic strategy performed worst of all. The differentiation strategy was characterized as one supporting a high level of service quality with high prices and high rewards for their employees. In contrast, the low-cost strategy is characterized by firms attempting to produce the motor carrier service output at the lowest possible cost. Finally, the firms using the broad product and geographic strategy are those covering the widest geographic area and handling a greater mix of TL shipments (with their primary LTL basis) of all the identified strategies.

Furthermore, the study found that although the mere act of changing strategic focus during the transition did not guarantee better performance, certain types of strategic changes had effects that enhanced profit. Specifically, firms moving from a product focus to a differentiation strategy improved their profitability. Likewise, firms moving from a regional focus to a differentiation strategy and those moving from a broad product and geographic focus to a low-cost one were also successful. A separate study has investigated the factors that best explain the factors enhancing the likelihood that firms will make a strategic change during the transition to deregulation (*9*).

Overall, the new competitive environment challenged firms to adapt their strategic focus to the new circumstances. Although there was a general profitability decline among the LTL firms, the firms making specific strategic changes were able to perform at a level consistent with average firm performance under regulation.

Firm Size Advantages in Deregulated Environment

Although an examination of costs and revenues for LTL carriers during the transition period provided direct evidence of substantial market competition, the evidence of increased concentration among LTL carriers is a source of concern among some analysts (*10*).

Many industry analysts have argued that the new competitive environment gives distinct advantages to large firms and corresponding disadvantages to smaller firms. Large firms have broad geographic coverage and the ability to handle all the shipping needs of customers

committed to consolidating their transportation business with a limited number of carriers to improve their bargaining position (*11*). One author has characterized the advantages to large carriers as "marketing economies" (*12*). A recent investigation of the effects of firm size, combined with firm strategic focus, on performance demonstrated the disadvantages of small size in a deregulated environment. The authors found that

> when the effects of firm size are coupled with strategy selection, the disadvantage of small size in the deregulated environment is even more striking. Overall there is no strategy that results in significantly better performance for small firms. When large firms couple their size advantage with a particular strategy, such as differentiation, regional focus, or contingency, their superiority over the small LTL firms is even more significant. (*13*,p.142)

This picture contrasts sharply with the regulated environment, in which firms attempting to exercise their size advantages were hindered by regulatory decisions designed to enhance the profitability of the "averaged-sized" firm.

This experience under deregulation deviates from econometric evidence regarding the relationship between firm size and costs. The overwhelming consensus of the literature has been that there are no economies of scale in the LTL sector in either the regulated or the deregulated environment (*14*,*15*). In fact, the previously cited study indicating the disadvantages of small firm size in a deregulated environment also found that

> medium-sized firms perform close to the level achieved by large firms. In fact, medium-sized firms pursuing a differentiation strategy outperformed large firms pursuing any individual strategy. Thus, small firms need only increase their size slightly (to the level of medium-size firms) to remove their disadvantage. These results do not support the contention that only the very largest motor carriers can succeed in the deregulated environment. (*13*,p.142)

A recent review of the performance of LTL firms found that "regional LTL carriers continued to leverage their service and labor cost advantages to outperform the nationals. The operating margin for the regionals appears to be stabilizing at about 9 percent, or three times the average for the nationals" (*16*,p.6).

In conclusion, even though traditional econometric studies have not found any statistical economies of scale for LTL carriers, there has been no increased concentration of business among the largest carriers. The source of advantage for the large firms may very well be in the area of marketing economies or density economies associated with higher levels of output per terminal or per route mile. In fact, recent work has established the existence of terminal and line-haul density economies among the LTL carriers (*17*,p.35;*18*).

Despite the advantages to large firms, there is reassuring evidence that medium-sized firms can do quite well. In fact, there is evidence that these firms outperform the very largest LTL carriers. Thus, any public policy action regarding the evils of increased competition appears to be unwise and unwarranted.

Range of New Strategies Among LTL Firms

Although the overall profitability of the LTL sector has deteriorated since deregulation, individual firms pursuing appropriate strategies have maintained levels of profitability approaching those reached in a protected, regulated environment.

The new competitive environment has challenged carrier managers to redefine their business focus and innovate with new services and business plans. It is clear that the 1990s will contain an acceleration in strategic experimentation.

The managers of the largest LTL firms, recognizing that the growth in the size of the LTL market is not keeping pace with the growth in the overall small-shipments market (Figure 6), have expanded into new services in an attempt to increase growth rates while rationalizing

their core LTL network. Joseph M. Clapp, President and Chairman of Roadway Services, Inc., summarized his firm's differentiation strategy like this:

> At Roadway Services, we've been working hard on this matter of differentiation for awhile. And I honestly believe we are seeing that happen. Back in 1980, Roadway Express was a pure play, long haul LTL carrier. Today, Roadway Services is a multi-modal provider of transportation and logistics services. Roadway Express is a North American network LTL carrier. Roadway Services had four regional carriers focused on highly dependable overnight distribution services to their area markets. We have a business-to-business small package carrier reaching 80 percent of the population in 43 states. We have a highly successful critical-shipment, time-definite carrier providing very specialized precision deliveries. We have another company that provides integrated logistics services. (*19*)

Roadway has become the prototype LTL firm that has transitioned from the highly protected regulated market to the intensely competitive deregulated market. The role of the national LTL firms has reached its peak. The major national LTL firms have shown definite signs of rationalizing their networks by closing some regional consolidation terminals (*20*). The emphasis has shifted somewhat toward delivery of fast, high-quality service to customers who require on-time deliveries to meet the just-in-time inventory schedules of today's global economy. In many situations, regional, often nonunion, LTL carriers are in the best position to provide these time-sensitive deliveries. As stated by a leading industry analyst,

> the interregional carriers . . . tend to have more productive labor. They tend to be nonunion carriers, several of which are located in the Southeast. They tend to have faster transit times because they don't break the freight as often en route, and they are able to offer tailored service packages because they're not constrained by unwieldy union work rules. So, interregionals are picking the pockets of the larger national carriers. (*1*,p.19)

The global economy of the 1990s will place significant emphasis on efficient, highly integrated logistics systems. Transportation firms able to respond to these very sophisticated shipper needs will be in the best position to reap significant rewards. The main drive behind the move by the national LTL firms toward the establishment of independent third-party logistics services is the recognition that shippers face an increasingly complex array of transportation price and service options and need guidance in creating an integrated logistics system. The aggressive, innovative national LTL firms, such as Roadway, are positioning themselves not only to design integrated logistics systems through their independent third-party logistics subsidiary, but also to provide possible transportation services associated with an integrated logistics plan. The array of services include the core, national LTL business along with regional LTL services, time-sensitive package express, and air freight deliveries.

TL Industry Segment

Overview

Like the LTL segment, the TL segment of the motor carrier industry has undergone tremendous changes in response to the new regulatory environment. As anticipated by proponents of deregulation, firms in this segment lowered their costs and improved their efficiency in adapting to the new regulatory conditions. As a reflection of the strong competitive forces at work in this segment, these improvements have been passed on fully to the shippers as lower prices.

Just as in the LTL segment, certain firms in the TL segment recognized that they could achieve large gains through strategic innovation. An entire class of carriers, commonly referred to as "advanced truckload" firms, emerged with a cost structure that clearly outpaced industry

competitors. The advanced TL firms focused on high-density, long-haul corridor traffic for their primary business, and they were well-rewarded for their efforts.

The growth of and openings gained by the advanced TL firms were challenged as a result of the spread of the double-stack container trains initiated in the 1980s. This service, used to move import containers from Japan through the West Coast to markets in the Midwest, East, and South, provided excess capacity for moving domestic traffic from these regions back to the West Coast. Through an aggressive pricing structure, the double-stack operators began filling this excess capacity and taking over some of the traffic of the advanced TL firms.

However, the advanced TL firms as well as other innovative TL firms have responded aggressively to the double-stack encroachment through a number of important strategic initiatives: forging intermodal partnership agreements with railroads, committing to containerization, and shifting to shorter-haul markets with shipper-carrier partnerships to minimize shippers' total logistics costs.

Cost Reductions, Productivity Improvements, and Price Reductions

Table 3 displays the shifts in operating costs and revenues (measured in 1987 constant dollars) among the TL carriers in each of 10 different TL segments. [This section of the paper draws primarily from work by Corsi and Stowers (*3*).] Table 3 indicates that in all but 1 of the 10 TL segments listed, operating expenses per mile and operating revenue per mile decreased significantly in real terms between 1977 and 1987. The highest percentage decrease in real per-mile costs occurred among the TL general freight carriers (55.8 percent decrease), which was followed by decreases of 27.8 percent among heavy machinery carriers and 27.2 percent among refrigerated carriers.

In seven of the nine segments with a decrease in real per-mile operating costs, the decrease in real operating revenue per mile outpaced slightly the decrease in costs. This is direct evidence that the anticipated positive gains from a competitive market are in effect: all reductions in costs are passed on in full as lowered prices.

As among the LTL carriers, the TL carriers were able to achieve lower costs through savings in direct expense items as well as improved efficiencies. For example, among the TL general freight carriers, the annual miles per power unit increased from 35,400 in 1977 to 73,400 in 1987. Furthermore, the TL general freight carriers increased their average loads from 9.1 to 13.2 tons and their average lengths of haul from 176 to 467 mi. In a similar fashion, other specialized commodity haulers increased their average annual miles per power unit from 60,400 to 67,000 and their average loads from 12.0 to 13.6 tons. [The TL general freight category defined by the ICC and used in this analysis consists of carriers with general freight as their primary commodity and TL transportation as their primary activity. In 1977 carriers in this group had a mixture of TL and LTL general freight. In 1987, however, carriers in this group focused on TL general freight to the near total exclusion of LTL activity. Thus some of the differences in cost and revenue per mile, power unit utilization, average load, and average length of haul may reflect the exclusion of the LTL traffic by the TL general freight carriers.]

Thus, as it was among LTL carriers, the transition to deregulation among the TL carriers meant competitive pressure to reduce costs and to pass along cost savings to customers. Furthermore, efficiency gains played an important role for TL carriers in achieving lower costs.

Strategic Repositioning: Advanced TL Firms

The post–Motor Carrier Act environment of intense competition in the TL industry sector challenged motor carrier managers to be innovative in order to gain market advantage. Obviously, the new competitive conditions allowed the failure of managers who were slow to adapt or made strategic errors. No longer did a regulatory umbrella protect managers from the consequences of their own decisions.

TABLE 3 TL Carriers: Shifts in Costs and Revenues, 1977 to 1987 (*3*,p.23)

Industry Segment	Year	Expenses ($)	Change (%)	Revenues ($)	Change (%)
TL General Freight	1977	4.07		4.25	
	1987	1.80	-55.8	1.86	-56.2
Heavy machinery	1977	3.49		3.56	
	1987	2.52	-27.8	2.51	-29.5
Petroleum	1977	2.07		2.16	
	1987	1.80	-13.0	1.85	-14.4
Refrigerated	1977	1.91		1.97	
	1987	1.39	-27.2	1.43	-27.4
Dump trucks	1977	1.81		1.89	
	1987	1.68	- 7.2	1.73	- 8.5
Agricultural	1977	1.58		1.63	
	1987	1.40	-11.4	1.41	-13.5
Motor vehicles	1977	2.15		2.25	
	1987	2.20	+ 2.3	2.28	+ 1.3
Building materials	1977	1.95		2.00	
	1987	1.50	-23.1	1.54	-23.0
Forest products	1977	1.36		1.42	
	1987	1.29	- 5.2	1.34	- 5.6
Other	1977	2.33		2.43	
	1987	1.73	-25.8	1.76	-27.6

NOTE: Expenses and revenues are per-mile measures in 1987 constant dollars.

Not surprisingly, as observed in the previous section on the LTL sector, there were carriers in the TL sector whose managers moved aggressively in the new environment to offer a much-improved level of service at a cost substantially below the level that was being offered. This combination of improved service at lower costs enabled certain innovative TL carriers to gain market advantage. A previous study has investigated the strategic approaches used by carriers in the TL general freight segment of the industry and evaluated the success or failure of firms that used these strategies (*21*).

A specific group of TL carriers with a particularly innovative strategic focus has been identified as advanced TL operators (*1*,p.7;*22*). These firms broke from the pack in the years after passage of the Motor Carrier Act by competing for long-haul traffic in high-density corridors. They employed an innovative management approach that resulted in costs far below those of traditional TL carriers and in service far above the industry standards. These advanced TL firms use driver teams and relays, as compared with the single-driver owner-operator, to keep tractors operating more hours per day, with a significant increase in annual tractor

mileage. These firms have found that their rapid growth, plus the use of company drivers, allows them to buy equipment in large quantities and achieve discounts of up to 20 percent. These operating practices and their associated cost savings combined with a very sophisticated computer load matching capability focused on securing freight in long-distance, medium- to high-density corridors with balanced traffic flows. "In combination, these factors result in empty mileage in the 6 to 8 percent range, as opposed to the 15 to 20 percent empty mileage rates that are typically achieved by more traditional TL firms" (*3*,pp.11–12).

The advanced TL firms experienced rapid expansion and high profitability through the 1980s. One source has summarized the success of these firms as follows:

> The 1980s were a period of rapid growth [among these advanced truckload firms] with 30 to 40 percent annual revenue increases for many carriers, including J. B. Hunt, Schneider, Werner, and MS Carriers. At the beginning of the 1980s, Schneider's total revenues were $250 million increasing to $908 million in 1991. . . . J. B. Hunt began the decade with $25 million on the top line and finished 1991 with $732 million. Werner Enterprises grew from $94 million in 1986 to $323 million in 1991, while MS Carriers went from $35 million to $152 million over the same time span. Extraordinary growth rates for these predominately non-union truckload carriers were achieved by continually lowering costs through intensive equipment utilization. Relatively low-cost operations enabled many carriers to capture truckload freight from the national LTL carriers, long-haul private fleets, and rail boxcars. (*23*)

Thus, the move to a competitive environment enabled carriers to innovate and experiment with various strategic approaches. As observed with the LTL carriers, among the TL carriers certain strategic approaches were more successful than others. The management and operating practices of the advanced TL firms emerged as a highly successful approach under the new market conditions.

Double-Stack Challenge and Response by Innovative TL Firms

In the 1980s, steamship lines (American President Lines, in particular) introduced double-stack train service in the United States as a way to move containers (for imports and exports) in an efficient manner. In an effort to avoid the movement of empty containers back to the West Coast (because of imbalances in trade between the United States and Japan), steamship operators began offering the empty container capacity for domestic traffic from the markets in the Midwest, East, and South to the West Coast. The steamship operators were able to offer this essentially back-haul capacity at marginal costs.

The double-stack service made some important inroads in the traffic of the advanced TL firms as a consequence of its price advantages. Experts have placed the costs of the line-haul portion of a double-stack trip at between 50 and 55 cents a mile. Even when terminal and drayage costs are added, most railroads still can transport a container for less than 80 cents a mile—a cost substantially below that achieved by the advanced TL firms (*24*,p.2C). The cost advantage combined with aggressive pricing resulted in traffic losses for the advanced TL firms.

Some advanced TL firms moved to answer the challenge of double-stack train operations just as they had moved after passage of the Motor Carrier Act. The following paragraphs outline a series of recent moves by advanced TL firms to re-establish their strategic position. It should also be noted that these "second-wave" innovations respond to a variety of factors and conditions beyond the double-stack challenge. Firms in the TL sector recognize that they need to anticipate and plan for changing circumstances and developments.

Intermodal Partnerships and Commitment to Containerization

J. B. Hunt, noted earlier as a prominent advanced TL firm, interpreted the challenge of double-stack operations as an opportunity to expand into intermodal operations. The entire double-

stack phenomenon demonstrated that rail service had improved enough to make intermodal operations a viable transportation service. J. B. Hunt believed that if it converted its trailer fleet to specially designed containers (predominately 53-ft containers) and chassis, it would have the option of using rail for line-haul service. Reliance on an improved rail intermodal service attracted Hunt because of its previously demonstrated cost advantage. An equally important consideration for Hunt was the availability of truck drivers. A series of developments had created real and long-term driver shortages. A recent summary of the driver issue and its effect on TL carriers such as Hunt concluded that

> in addition to competitive economics, another factor has led truckload carriers to look favorably on intermodal. During the 1980s, many truckload carriers experienced driver turnover each year in the 80 percent range. This was a result of drivers spending long periods on the road (3 to 4 weeks was common). High driver turnover was offset through 1990 by heavy recruiting from a pool of trained drivers. However, this pool has dropped dramatically during the past two years for three principal reasons: First, driver training schools were funded by federal student loans that have been shut down because of high loan default rates. Second, drug testing has become mandatory. Third, the National Commercial Driver's License has pushed bad drivers out of the industry. (*23*)

These factors led J. B. Hunt into a series of intermodal partnership agreements with several individual railroads [including Burlington Northern, Consolidated Rail Corporation (Conrail), Southern Pacific, and Union Pacific] to provide line-haul service for Hunt's containers. Hunt has committed convert its fleet to containers over the next 5 years. In this regard, Hunt has ordered 10,000 containers for delivery in 1993 (*25*). The importance of this intermodal traffic to Hunt is summarized in the following statement:

> During 1991, J. B. Hunt tendered nearly 42,000 intermodal loads, generating $72.7 million in intermodal revenue compared to its $690 million for over-the-road operations on 720,000 loads. Thus, for J. B. Hunt, the intermodal portion accounted for 6 percent of its total loads while generating 10.5 percent of total revenues. Hunt has publicly forecast $150 million to $160 million in intermodal revenue for 1992. (*29*)

Other leading advanced TL firms have begun rail intermodal partnership agreements as well. Schneider National began intermodal agreements with Southern Pacific in 1991. In 1992 Schneider entered agreement with Conrail. Schneider expects continued growth in revenue from intermodal operations into the future (*23*). Other notable examples are MS Carriers Inc. and KLLM Transport Services, Inc. (*26*).

Shifts to Shorter-Haul Markets with Shipper-Carrier Partnerships

Another response to the challenge of double-stack rail service on the high-density, long-haul corridors has been for the advanced TL firms to direct more attention toward securing business on shorter-haul regional markets. To improve their share of this business, individual TL firms have initiated carrier-shipper partnerships in which the carrier becomes directly involved in the logistics systems of the shipper in an effort to minimize total logistics costs.

The importance of the shorter-haul regional markets should not be underestimated. A recent report has estimated that 70 percent of total revenues in the TL segment come from shipments of fewer than 500 mi (*1*,p.17). A number of the advanced TL firms are expanding their business in these short-haul markets. J. B. Hunt, Schneider National, MS Carriers, Swift Transportation, and Heartland Express are just a few of the prominent carriers that have expanded their short-haul opportunities in the past several years (*27*).

Service reliability and on-time performance are key elements of effective participation in the short-haul markets. In this regard, the advanced TL carriers have worked to develop strong partnerships with shippers to minimize logistics costs. Shippers have become willing to devote a substantial portion of their business with so-called core carriers that will allocate resources to deliver a high-quality service.

In many carrier-shipper partnerships, the carrier makes a commitment to deliver high-quality service in exchange for a commitment by the shipper to concentrate business with their carrier partner (*28*). In some cases, the carriers have added satellite- and land-based mobile communications and tracking systems to monitor the location of their power units and supply the shippers with real-time information about shipment location (*29*). These capabilities have significantly enhanced the quality of their service and enabled the carriers to improve productivity of their equipment.

Summary

Clearly, the message of the new competitive environment is that certain TL firms will respond quickly and aggressively to any challenges that may arise. When the initiation of double-stack service pointed out the workability and cost advantages of intermodal service, advanced TL firms established partnerships with railroads.

In addition, TL firms moved to strengthen their positions in the short-haul markets by creating shipper-carrier partnerships. These partnerships provided TL carriers with the business commitments necessary to allow them to invest in productivity-enhancing advanced technologies.

New Markets and Opportunities for Innovative TL Firms

The new competitive environment has challenged TL firms to find new markets and opportunities. Two interesting markets not yet fully exploited are conversions of private fleet activity and access into large LTL shipments. However, ability of the TL carriers to expand into new markets is directly affected by the driver shortage issue.

A leading transportation analyst has estimated the size of the private fleet conversion market that is available for TL carriers:

> Plenty of opportunities for private-carriage conversion still exist in this market. . . . There is roughly $85 billion worth of private fleet business available for conversion. Even if only $5 billion to $10 billion of that can be converted over to truckload common carriage or dedicated contract carriage, it seems . . . that there is a huge opportunity here for the short-haul specialized carriers. (*1*,p.11)

Certainly the efforts by the advanced TL firms to improve service quality, efficiency of operations, and productivity indicate a strong desire to obtain additional conversions of private fleets.

Another opportunity for new business for the TL firms involves large LTL shipments. In the previous section on the LTL firms, it was demonstrated that air freight and specialized small package carriers had penetrated the LTL business for small packages. In the same manner, very large LTL shipments are subject to diversion to TL carriers. Through innovative marketing and pricing, the TL carriers could fill a container or trailer with a limited number of large LTL shipments. If these shipments were destined to a limited number of drop-off points, it would be possible for the TL carrier to make the movement. Alternatively, the TL carrier could pick up a limited number of large LTL shipments bound for the same region and negotiate with an LTL regional carrier to distribute the shipments within that region. Of course, the ability of the TL carriers to develop an inroad into the large LTL shipments requires special traffic flow patterns combined with innovative marketing and pricing. Advanced TL firms are pursuing these options, nonetheless.

As noted, any of the identified market opportunities for the TL carriers is limited by the extent to which the nation faces a driver shortage. The adoption of drug testing in combination with the commercial driver's license has shrunk the pool of available drivers, but obviously the drivers being eliminated from the pool are precisely the ones that should be taken off the road.

These new developments have changed the position of the truck driver in the eyes of the TL carriers. TL firms now have direct incentives to improve driver wage and benefit packages in an

effort to retain more drivers and, thereby, reduce costly turnover. Part of the motivation of the advanced TL firms to pursue intermodal partnership agreements with railroads was a desire to cut down on drivers' on-the-road time and limit the need for additional manpower (*30*).

Owner-operators, particularly the more experienced ones, were shunned initially by the advanced TL carriers because of their independence and lower productivity levels than driver teams, but they have reemerged as an alternative. They look especially attractive to firms trying to establish themselves in new markets, since they represent an opportunity for such firms to add capacity with a minimal fixed investment (*31–33*).

In any case there will be continuing concerns about the availability of qualified drivers during the 1990s. These concerns will at the very least dictate improved wage and benefit packages for the TL drivers and, as a result, some increases in costs. At the very worst, the driver shortages will constrain the opportunity of the TL carriers to move into new markets.

Future Issues and Conclusions

Several important issues and developments will affect motor carriers in both the LTL and TL segments. These issues will be discussed, and associated policy options will be presented. The paper will conclude with a discussion about the type of industry data needed to address policy questions and the specific nature of research studies needed to provide guidance to policy makers.

Intrastate Deregulation

Although a few states have deregulated motor carrier service, most continue to regulate it. The recent Supreme Court decision freeing Federal Express from all regulations in California will quickly achieve what economists and other policy makers have been advocating for years, that is, intrastate deregulation of all motor carrier services. It has long been argued that the remaining intrastate regulation of motor carriers operations is out of sync with interstate deregulation and results in motor carrier service that is inefficient and more expensive (*34,35*). Exact estimates of the magnitude of the direct additional costs associated with intrastate regulation vary widely, but these costs are substantial. There are many examples of regulatory inefficiencies associated with these intrastate regulations. Firms have moved production operations out of state, farther from markets, in order to avoid the use of intrastate, regulated motor carrier services.

It is anticipated that the Supreme Court decision with respect to the operations of Federal Express in California will put direct pressure on Congress to develop a unified response to the problem. It is clear that the major motor carrier interests will be lobbying Congress to put them on an equal footing with Federal Express. It is hard to imagine a solution to the California situation that will not involve fixing the entire problem and eliminating intrastate regulations. The recommended solution involves federal preemption of restrictive state motor carrier regulations.

Truck Size and Weight Considerations

The direct issue of truck size and weight regulations is the subject of other papers, but a few considerations appear to be appropriate for this paper. It seems that almost without exception, various investigations have concluded that substantial productivity gains are to be achieved by increasing truck sizes and weights (*36*). Important issues of public policy remain, however, especially concerning safety and rail diversion. Yet in examining the history of truck size and weight regulations, it appears clear that there will be changes and that those changes will be toward increased sizes and weights. It is hoped that the move in this direction will result in a more cohesive system than the current patchwork of exceptions and grandfather clauses that

currently constitutes our national policy. Efforts to achieve such cohesion have proven very difficult in the past, though, and the author is only cautiously optimistic that they will be successful in the future.

The movement by the TL carriers toward intermodal partnerships with the railroads is an encouraging development in the debate over truck size and weight. One of the biggest misconceptions is that any increases in size and weight will result in damaging diversions from rail service. What the TL intermodal partnership agreements have shown is that if rail service is of a quality high enough to allow its cost advantages to dictate results, rail traffic will do quite well if truck size and weight are increased to a limited degree. Unfortunately, the issue of truck size and weight has suffered from the infusion of hysteria through inappropriate advertising "scare" tactics. A more reasonable discussion of the issue might yield more appropriate public policy.

If truck size and weight are increased, truck productivity will be enhanced. Furthermore, some of the concerns about the availability of qualified drivers will be erased. The resultant decrease in demand for drivers would, hopefully, allow carriers to hire only the most qualified drivers. Such actions by the carriers would have some positive impact on highway safety.

The country would be better served if the truck size and weight policy were accorded greater cohesion on sizes and weights on a national level, better recognition of the productivity benefits associated with higher weights and sizes and vehicles with appropriate safety design considerations incorporated, less hysteria, and a more reasoned approach to the rail diversion issue.

Concerns About Structure of LTL Industry Segment

Several prominent authors have warned that the increase in concentration among the LTL carriers (as documented earlier in this paper) will lead to a near monopoly in this segment. According to Boyer,

> it is impossible to predict at this point how far the concentration of the American trucking industry will proceed. The industry may ultimately resemble the inter-city bus industry or the small package delivery service, each of which are organized essentially as monopolies (Greyhound and UPS, respectively). It is more likely that the industry will come to look like the U.S. airline industry in which traffic is dominated by a handful of carriers with national coverage or like the for-hire trucking industries of other nations in which as few as three or four carrier have dominant shares. (*10*;*37*,p.485)

The notion that the LTL industry segment will turn into a virtual monopoly or, at best, a limited oligopoly, appears to be at odds with the facts presented earlier in this paper. The increase in industry concentration is undeniable. However, the adverse monopoly-pricing consequences associated with the increased concentration have not materialized. The real cost of LTL services and the real prices charged to the shipping public have decreased significantly in the years since the passage of the Motor Carrier Act. Such costing and pricing behavior is not evidence of monopolies.

The most profitable LTL carriers in the past few years have been the regional ones. These carriers have appeared in a better position to offer faster service to shippers (with regional origin-destination patterns). In fact, the major LTL national carriers have taken direct initiatives to improve their service times and reliability in selected regional traffic lanes in response to the actions of the regional LTL carriers.

In the face of the direct evidence of significant competition among the LTL carriers and the success of the regional LTL operations, it is hard to agree with Boyer's conclusions. Having said this, it is equally important to stress that several questions about motor carrier operations must be answered if the future market structure of the LTL carriers is to be understood comprehensively.

There should be a clearer understanding of the impact of firm size on LTL carrier performance. Even though the econometric studies show no economies of scale, it is known that firms tend to be getting larger in this segment. The effects of size on performance need further

investigation. The advantages of size may not strictly involve size, by itself, but may also involve economies of density—that is, firms may be able to reduce costs and gain advantages by increasing the density of traffic over their networks. The only way for the firms to increase their traffic densities, however, may be to increase their size and market access.

However, economists have not answered these questions since the data available in readily accessible form are inadequate. To show density economies, researchers need data on the route structures (and route miles) of the LTL carriers. Such data were collected and reported on routinely by the ICC in the regulated era, but the data are no longer reported and not readily available. The ability to show that LTL firms have density economies would require obtaining route structure data on a systematic basis for all involved firms. The author believes that such a study would show that the real cost advantage for LTL firms involves density economies (i.e., increasing traffic over a fixed-route structure). It is certainly arguable that large firms have a greater likelihood than do small firms of having high traffic densities. But it is also conceivable that regional firms with high service levels and intensive marketing could achieve high traffic densities as well.

The author believes that the concerns of researchers such as Boyer and Dempsey that the LTL industry is heading toward a monopoly situation could be better addressed if systematic research were undertaken to show the impact of traffic density on firm costs. This is an important policy question and should receive priority attention and funding for a research project.

Concerns About TL Industry Segment

For years economists wrote about the economic advantages of intermodal (rail-truck) services for long-distance hauls. Yet throughout the 1960s, 1970s, and into the 1980s, the growth in intermodal services never met the economists' expectations. The initiation of double-stack train service in the 1980s finally provided the impetus for a rapid growth in intermodal services.

As noted, the growth in double-stack service, coupled with serious concerns about truck driver availability, led a number of advanced TL operators to initiate partnerships with railroads for intermodal services. Operators such as Schneider and J. B. Hunt have pursued such partnerships aggressively. These carriers, through their size, are in a position to direct the nature of TL services offered to the shipping public.

It appears clear that the major TL operators recognize that the economics of long-haul shipping dictate intermodal partnerships. The commitment by these operators to intermodal operations will cause sharp reductions in the amount of long-haul, cross-country trucking operations. Much more TL service will be provided through intermodal partnerships between major TL carriers and the railroads. This development has significant repercussions for a variety of actors in the transportation scene: owner-operators and truck drivers, railroads, and TL operators.

The fortunes of the owner-operators have risen and sunk through the adjustment to deregulation. It now appears that those owner-operators who have survived these difficult years with excellent safety records will be in high demand. The notion of driver shortages, although mitigated by the shift to intermodal operations, is still real. Owner-operators just starting in business will have a difficult time gaining employment, which will have serious implications as the current corps of owner-operators reaches retirement age.

The shift to intermodal partnerships for long-haul trucking operations will mean that fewer owner-operators and truck drivers will be involved in cross-country, multiple-week trips away from home. The norm will be a series of regional trips (300- to 500-mi) with a fixed route and home base. This change in operating patterns will most likely have a tremendous favorable impact on the available pool of drivers.

The railroads will probably gain significantly from the increasing reliance placed on their services by the TL carriers. The ability of the railroads to deliver high-quality intermodal services is the biggest change in making such operations attractive in the marketplace. In the

1960s and 1970s, whereas the economics may have indicated that intermodal services were competitive, railroad service was totally inadequate to provide a competitive threat. The streamlined and efficient railroads of the late 1980s and 1990s can now provide a competitive service. It certainly can be argued that the railroads needed to be freed from the regulatory restraints and to be completely restructured so that they could realize their competitive advantage in the marketplace.

The growth and prominence of large advanced TL carriers raise some questions about the emerging structure of the TL industry segment. It is clear that carriers such as J. B. Hunt and Schneider are dictating some fundamental changes in the type of TL long-distance services available. The real question is whether the marketplace will continue to have places for smaller TL carriers that offer different kinds of services. As with the LTL carriers, the TL carriers have experienced some significant increase in concentration. However, the author thinks a similar argument can be made that the TL marketplace, like the LTL marketplace, will allow for a variety of carrier types and services. The marketplace results from the first decade of operations under deregulation show no signs of monopoly power. Carriers are engaged in a fierce competitive struggle for business. A few carriers, such as J. B. Hunt and Schneider, are growing rapidly, but there is no evidence that the TL industry segment will gravitate toward an oligopoly. Smaller niche carriers are competing effectively right alongside the large players.

Service and Pricing Concerns in a Deregulated Market

Although the data presented in the analyses of the LTL and TL segments showed significant decreases in the real price of motor carrier services, some critics have argued that the gains from deregulation have been uneven, concentrated among the very large shippers with strong economic power over the carriers. They point out that such favoritism toward large manufacturers has disastrous impacts on the U.S. economy and its reliance on the small entrepreneur. According to Dempsey,

> Professor Donald Harper has noted that the ability of small shippers to compete against larger rivals is hindered by relatively higher freight rates. Hence, discriminatory transportation costs contribute to the economies of scale that larger entrepreneurs enjoy throughout the American economy. The higher cost of access to the stream of commerce endured by small shippers places them at a competitive disadvantage vis-à-vis their larger rivals. Assuming all other factors are equal, the large manufacturer with relatively (and, in many cases, significantly) lower transportation costs will be able to market his product at a lower price than his smaller counterpart. Deregulation facilitates this discrimination. These deleterious economic consequences have a broader social impact, for small businesses create most of America's jobs. (*10*,pp.58–59)

There are several fundamental fallacies in this line of reasoning. The first problem is that it assumes that motor carrier rates under regulation involved no elements of discrimination. This is quite wrong. The entire rate classification system and the manner in which the regulated carriers implemented the system involved systematic elements of discrimination. Furthermore, many of the discriminatory aspects of the rate classification system and its application were not based in any cost differences.

Second, under deregulation, there may be clear differences in the rates charged to large shippers than to smaller shippers, but these differences are based on differences in cost. Hence, it is inappropriate to call these rate differences discriminatory. To the extent that the differences in deregulated rates for the large and small shippers are not cost-justified, the expectation is that the differences could not be maintained in the long-run. The conclusion is that the deregulated environment will result in a rate system that is cost-based. Congress has declared that the cost-based system is preferable to the previous system. There is a recognition that the larger shippers may be able to obtain lower rates, but such differences are a consequence of lower costs of service.

International Market Opportunities and Open Borders

The emergence of a global economy is becoming an accepted fact in the transportation world. U.S. motor carriers are recognizing that they need to develop business links beyond the 48 continental states. In this regard, selected carriers have been pursuing opportunities in Mexico, Canada, and even Europe and Asia.

The signing of the North American Free Trade Agreement signals a new era in trade among the United States, Canada, and Mexico. A number of major U.S. motor carriers are pursuing opportunities aggressively. They recognize that the free trade agreement has the potential to expedite the movement of manufacturing capacity south of the border and increase the demand for international movement of products into the United States. Still, many issues need to be resolved regarding the participation of U.S. motor carriers in Mexico and Canada as well as the participation of carriers from these countries in the United States. Further complicating these considerations are the various truck size and weight laws in the three countries involved.

Some U.S. motor carriers have set up non-vessel-operating common carrier (NVOCC) subsidiaries to handle their international shipments to Europe and Asia. In addition to establishing the NVOCCs to handle the ocean portion of the international movement, the U.S. carriers have reached agreements with foreign-based motor carriers or foreign NVOCCs to deliver the freight (*38*). U.S. motor carriers contend that they have initiated these services in response to customer demands for a single-carrier responsibility for the entire movement.

Clearly, the future will see a significant enhancement of international shipments in response to the increasingly global economy. It appears necessary for U.S. motor carriers to position themselves to make strategic gains from these developments and to ensure that foreign motor carriers (especially from Canada and Mexico) do not gain unfair advantage at the expense of the U.S. carriers.

Data Needs and Research Opportunities

The previous discussion has presented an argument in favor of a research stream designed to investigate the relationship between motor carrier firm size and associated cost advantages. In that connection, it was argued that size effects must be combined with density economies in order to realize marketplace cost advantages. However, the substantiation of this argument will require the systematic collection of LTL firm route structure information to enable researchers to construct density measures (i.e., tons or ton miles divided by route miles).

Several other research topics merit systematic investigation. This paper has investigated the changing dynamics of competition in the LTL and the TL segments, but there are definite data gaps in this area. Often there is some aggregate information about how the total TL or LTL traffic is divided among the various competitors. However, rarely is there information on traffic lane/state-to-state competition among the modes. In effect, the level of aggregation is too great for researchers to understand in complete terms the dynamics of intermodal and intramodal competition.

It is with great anticipation that transportation researchers await the availability of new Census of Transportation data, which will provide for the first time in more than 20 years systematic data on intermodal competition in all the various transportation markets on a geographic-specific basis. The analysis of these data will yield significant insights on the changing nature of intermodal competition in the dynamic deregulated environment.

Conclusion

The motor carrier industry has experienced rapid change as a result of the transition from a highly regulated to a competitive market. This environment has been particularly harsh to carriers without the foresight or the wherewithal to make strategic adjustments to cope with new circumstances.

This paper has documented the major changes in both the LTL and the TL segments of the industry. It has focused on carriers that anticipated marketplace changes and moved aggressively to position themselves to take advantage of the changed opportunities. Clearly, the new environment enabled carriers to be successful if they made good decisions, but it hurt carriers whose managers were not as skillful in adapting to the situation.

However, the overriding consideration in evaluating the transition period is that the type of motor carrier service being delivered in the 1990s is one that is of much higher quality and that benefits from sizable efficiencies. It is hard to imagine that the innovations presented in this analysis would have been possible had Congress not passed the Motor Carrier Act of 1980. Although the transition has not been without its rough spots, the general direction of the changes has been positive. Any serious discussion of a return to the very complacent regulatory environment is almost inconceivable. Certainly, the highly competitive global economy dictates that all U.S. activities be conducted in the most efficient manner possible. This, of course, requires a continuing commitment to a competitive environment free of governmental economic regulations.

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Summaries of Panelists' Comments

Russell B. Capelle, Jr., *Massachusetts State Transportation Planning Staff*

In looking for common themes between the two papers, a recent Transmode project came to mind. [At the time of the symposium, Cappelle was associated with Transmode Consultants, Inc.] Transmode worked for the Eno Transportation Foundation of Lansdowne, Virginia, carrying out a survey of major transportation associations and organizations to find what issues were most important to them in 1993. I saw some similarity between many of the themes that associations think are "hot" and the themes in the two session papers. I provide the following as thoughts to munch on in the discussion sessions later.

We tend to name decades—the "Roaring '20s," the "Gay '90s," and so on. Some have called the 1980s the "Me Decade" because of self-centered grabbing by many for all they could get, moneywise and otherwise.

I propose that the decade of the 1990s in transportation is the "I Decade," but not for any self-centered reasons. It is because of the many high-priority issues that begin with the letter "I"! Let me provide you with a few sample issue identifiers:

- Inventory control. The concept of just-in-time logistics, trucks acting as rolling warehouses now more than ever, and the need to manage and control inventory to the best of a firm's ability are mentioned in both papers.
- Inventory/sales ratio. The decrease in this important logistics measurement is highlighted particularly in Coyle's paper.
- Integrated logistics is explained in both papers, and Coyle provides the Dow Chemical example that illustrates the concept.
- Intermediaries, particularly intermodal ones. Some of the trends covered in Corsi's paper result from there being in the 1990s a great many intermediaries such as third-party logistics firms, freight brokers, and consolidators who may put together several less-than-truckload (LTL) loads to create truckload (TL) movements, thereby contributing to the growth of the TL segment and the decline in the LTL segment.
- Intelligent vehicle-highway systems/commercial vehicle operations (IVHS/CVO). One of Coyle's "Drivers of Change" is technology, including IVHS/CVO of all types; he concludes that indeed "[i]t appears likely that carriers that do not move forward with available technology will be the business failures of tomorrow."
- Infrastructure. In the post-Interstate highway era as we plan for a proposed National Highway System, the word infrastructure is common in many legislative discussions and

transportation articles; planning for rehabilitation of the nation's highways, bridges, airports, port facilities, and other infrastructure is a high priority of the new administration.

- Incident management. In the post-Interstate highway era of repairs and rehabilitation of highways, there are many work zones that may contribute to congestion, if not accidents or incidents, disrupting the flow of traffic. Proper management of incidents rather than broad-based peak-hour congestion planning is often the key to keeping traffic moving.
- Information. Data systems, electronic data exchange, and other information issues are important in transportation now more than ever; with data bases disappearing in an era of tight budgets, we must use creatively and imaginatively the data systems we have available. Information is the strategic resource of tomorrow. Coyle mentions in his paper that computer systems "substitute information for inventory all along the supply chain."
- Internationalization. Companies need to think in global terms now, with many international issues of importance, such as the transborder Canada and Mexico issues in light of the North American Free Trade Agreement, European integration and positioning to compete with North America and Asian countries, and the need for containers to move intermodally from ports to mid-continent markets thereby fueling the current truck-rail intermodal revolution in the United States.

And last but perhaps most important,

- Intermodal/ISTEA. Especially since the passage of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA), there has been almost a revolution in transportation as a substantial number of large TL carriers create alliances with rail carriers; the increase in truck-rail partnerships is covered by both Corsi and Coyle in their papers.

It does seem apparent from our vantage point in 1993 that the 1990s will be the "I Decade."

Gene S. Bergoffen, *National Private Truck Council*

Truck transportation must be a seamless part of the flow of goods for consumer use, said Gene Bergoffen. We need a new understanding of trucking that accounts for the great number of private trucking fleets as well as the roles of third-party services and new advanced technology.

Bergoffen went on to say that deregulation has effectively displaced private trucking firms from the long-haul trucking business; however, private firms still garner 57 percent of all trucking revenues—roles derived from both interstate and long hauls. This is attributable to the recent proliferation of small truck fleets able to operate at reduced costs per mile and increased productivity. Improving productivity and quality has been a major focus for private trucking firms. Even though private fleets are unique in that the operating companies are not in the trucking business, the issues are the same as those relevant to all modal choices and center on cost, service, and degree of control needed. Private fleets are alive and well today, but the main message from Bergoffen is that whatever trucking option is chosen, it must focus on the seamless movement of goods and services, using a global logistics strategy.

John McQuaid, *Intermodal Association of North America*

Intermodalism was not viewed as profitable by the railroads until the 1980s and is now on the threshold of revolution, instigated by a paradigm shift that has had far-reaching effects, observed John McQuaid. Railroads were largely persuaded to form alliances with trucking firms as a result of the push from members of the motor carrier industry, who were forced to search out new partnerships for their own survival. But even though some firms were "driven to the table," they have ended up benefiting from the service options and synergies evolving from these new partnerships.

The third beneficiary of this paradigm shift is the shippers, who can seek and find consistent, reliable, long-time service, regardless of the mode—"just do it, and get it there on time" is the philosophy, said McQuaid.

In commenting on the papers, McQuaid noted that the issue of globalization and what happens in the public policy arena—with the implementation of ISTEA, for example—was covered in neither paper. This is a significant issue because the global, not domestic, markets in which producers and suppliers are operating do not necessarily address the important investment decisions to be made about infrastructure at the local levels. The carrier and shipping industries need to work together in providing critical input at the local level to ensure that infrastructure needs are met.

WORKSHOP SUMMARIES

Present Trends and Future Demand for Goods Distribution

Anne Strauss-Wieder, *Port Authority of New York and New Jersey*

The demand for freight services is a derived demand, based on demand for the products of the industries being served, observed Anne Strauss-Wieder. The overall level of freight demand is affected by global, national, and local economic considerations; regulations (including modal and environmental); and technology (e.g., information can substitute for inventory). In terms of the composition of demand, manufacturing and service industries differ significantly. Moreover, the characteristics of freight services demanded include increased velocity, predictability, and the ability to handle additional transportation and distribution functions. Traditional demand by mode is changing, becoming amodal: the customer does not care what mode is used but is more concerned that the specified freight service is performed on time and on budget and is of high quality. Furthermore, transportation providers are now entering strategic alliances or partnerships with their shippers as part of a more cohesive, customer-responsive approach to distribution.

Discussion

Critical Technologies

Questions

- The public sector must obtain information to assist in the management of infrastructure, congestion, incidents/accidents, the environment, and safety issues. Who should generate, store, protect, and pay for this information? Who has access to it? How can it be collected with private-sector concerns in mind?
- Does demand drive technology or vice versa? (For example, either heavier loads or more vehicles are needed to move more goods; should technological solutions target vehicles or infrastructure?)

Comments

- New engine technologies (alternative fuels, electric) are also important to meet environmental concerns.

- Technology provides a means but not necessarily the solution: for example, although the technology to implement pricing solutions to congestion is available, political considerations are equally important.
- Technology adoption can be a challenge: not all customers are able or willing to use transaction- or cost-reducing technologies.
- Electronic customs clearance will be crucial in facilitating international goods movement.
- What should the public sector's role be in technology advancement?
- Does the private sector demand too much information from the public sector?

Modal Choice

Questions

- Where is the choice of mode being made?
- How does public policy influence modal choice? Examples of public policy that may affect modal choice include
  - –Regulations (e.g., Clean Air Act Amendments, Commercial Driver's License, and truck size and weight), equipment, and taxation; and
  - –Location of facilities (location is key, especially for ports and railheads).
- Are there institutional or regulatory barriers to partnerships and alliances?

Comments

- Requirements for nonattainment areas (for air quality under the Clean Air Act Amendments) could substantially affect modal choice.
- Labor issues could affect modal demand. Relevant labor issues include changes in a driver's job, work force availability, and ergonomic demands.
- The public sector still has difficulty thinking of freight from a multimodal or even an amodal viewpoint. Current data collection, for example, still reflects traditional modal definitions and may not capture trends.

Composition of Demand

- Issues include north-south versus east-west corridors of distribution, urban-rural logistical differences, changes in regional versus national production and distribution patterns.
- What are the elements of strong, lasting strategic alliances in transportation?
- What are the effects of intrastate laws on distance of transport, facility location, and congestion? Are they consistent with interstate policy objectives?

Recommendations

- The public sector has faced the problem of information acquisition and provision for a long time; now the challenge is to effect a paradigm shift such that information-related objectives are made explicit and facilitate mutually beneficial public-private collaborations. Specific information should be targeted for collection to answer explicitly stated questions.
- Looking only at single issues or interests results in poor decisions. A "full-vision" perspective is required to create a goods distribution system that will not be scuttled by microlevel problems or needs. Customers as well as carriers need to come to the political table (e.g., metropolitan planning organization meetings) if these points are to be made clearly; thus far, however, ISTEA seems to have pushed decision making to additional microlevels and has not effectively involved the private sector in freight issues. One possible solution is to identify the characteristics of successful private-sector strategic alliances and apply them to public-private collaborative efforts.

Structure of the North American Motor Carrier Industry

Randall G. Garber, *A.T. Kearney, Inc.*

Randall Garber introduced North American Motor Carrier Industry structure as one topic that encompasses a vast array of issues, and he encouraged the workgroup to focus on the most critical structural and operational issues facing the motor carrier industry today. Nine potential policy issues and data research needs were selected from Corsi's paper; these issues served as an outline for discussion.

Discussion and Recommendations

- *Should the federal government preempt state regulation?*

Intrastate regulation can range from physical equipment regulation (such as vehicle size and weight restrictions) to direct economic regulation (such as rate regulation). The group did not challenge the position taken in Corsi's paper that the federal government should move quickly to preempt intrastate economic regulation. Continued state economic regulation, Corsi argued, is incompatible with interstate deregulation.

- *In reference to truck size and weight regulations, do productivity gains outweigh safety and modal diversion concerns?*

Where there is a demand for larger trucks, lower transportation costs will result from increasing allowable truck size and weight; however, it is unclear to what extent such demand exists today, particularly given the trend to smaller, more frequent shipments. Furthermore, it was noted that increasing vehicle sizes and weights while lowering direct transportation costs per unit of freight carried may not lower total logistics costs because higher payloads might involve higher inventory costs.

- *Is growing concentration in the less-than-truckload (LTL) segment of the industry likely to result in a less competitive marketplace? Likewise, will the passage of the longer combination vehicle (LCV) legislation increase concentration in this segment of industry by increasing its capital requirements?*

The participants did not directly respond to the initial question. Regarding LCV legislation, it was noted that LTL carriers have distinct markets dependent not necessarily on vehicle or firm size, but on the carriers' ability to meet distinct service requirements, such as overnight and second-day markets. Multiple handling of time-sensitive freight will exceed more stringent time constraints. Regional LTL carriers are better positioned to meet these service require-

ments, but nationwide carriers are not structured to do so. To achieve full market penetration, nationwide LTL carriers must participate in the regional market arena by acquiring or consolidating with existing regional carriers. However, it is important to note that nationwide carriers may not choose to meet the demand for 1- or 2-day service because serving that market would involve significant operational changes.

• *Is concentration in the truckload (TL) segment of the industry likely to result in a less competitive marketplace?*

Even though increasing vehicle size and intermodal partnerships may result in some advantages to larger firms, the size and scope of the TL market is large enough to preclude domination by the largest firms. Additionally, intermodal options will continue to provide competition within the TL segment. There appears to be little support for imposing economic regulation to promote competition when free market forces appear to sustain competition and rationalize efficient industry structure.

• *Will driver shortages continue in the future? If so, what actions should be taken to alleviate the problem?*

There appears to be an "economic" driver shortage rather than a "physical" driver shortage. The economic shortage can be addressed with competitive wage levels and work schedule revisions that allow drivers more at-home time. Although relatively low profit margins restrain carriers' abilities to increase wages, it is doubtful that public policy actions are necessary or appropriate to resolve this issue.

• *Will demand for owner-operators continue in the future? If so, will new owner-operators be able to gain entry?*

The group appeared concerned that competitive market forces will continue to rationalize the use of and demand for owner-operators without the need for policy intervention. It was noted that owner-operators have been through some difficult times as a result of deregulation pressure to reduce costs and prices.

• *Do large shippers routinely receive rate and service advantages that are not cost-justified?*

The group noted that volume buyers in any industry demand favorable pricing, and the trucking industry is no exception. In an economic system that reacts quickly to productivity gains by reducing rates yet strongly resists price increases, it is difficult to suggest that any form of price regulation would produce greater social or economic benefits unless intrinsic benefits of small versus large firms exist—a position that appears to receive little, if any, support.

• *How do we resolve inconsistencies in international truck size and weight regulations?*

This discussion focused on three areas:

–A group representing industry and government positions should address United States-Mexico standardization issues. Although a National Motor Carrier Advisory Committee has been formed to address such issues, concern was expressed that the schedule for implementation (of transborder trucking) is preceding more rapidly than standardization and may result in confusion and inefficiencies in the short term.

–A limitation of the North American Free Trade Agreement (NAFTA) is its failure to address U.S. investment in the Mexican motor carrier market. Although cultural barriers will continue to provide powerful incentives for partnerships between U.S. and Mexican motor carriers, infusion of U.S. investment could improve productivity and service.

–Inconsistencies in U.S.-Canadian weight regulations are as much a function of the limitations in the United States' physical infrastructure (bridge conditions) as of political or regulatory issues. Until or unless this discrepancy is addressed, weight and regulatory differences will continue.

Group consensus indicated the need for a collective process of reconciling safety, productivity, and infrastructure requirements. Potential models for such a process include that of the Roads and Transportation Association of Canada (although concern was expressed that political influences must be secondary to factual input to be successful), the Commercial Driver's License development process, and the use of economic incentives similar to the approach taken in the Clean Air Act Amendments.

• *What research and data needs should be addressed?*

Although there was general recognition of the decline in the amount of motor carrier industry data available since deregulation, there appears to be little appetite for imposing

additional data-reporting burdens on carriers. Consequently, researchers must be increasingly creative in developing new data and more efficient in using the data that are available. In combining selected survey information with publicly reported information, researchers may be able to compile specific data needed to examine policy issues. For example, basic vehicle usage information might be collected to supplement the information currently gathered on new truck sales. This combination of sources could provide better insights on industry composition and size.

Specific research needs included the evaluation of scale and density economies in the industry. It is hoped that the current Census of Transportation will provide the traffic flow data needed for this research. An additional issue raised was the need to examine the impact of intermodal partnerships on driver retention; however, the advent of such partnerships is so recent that no sufficient data exist.

Intermodal Operations in the Present and Future

Edward K. Morlok, *University of Pennsylvania*

The session began with a short overview of issues by Edward Morlok. He suggested that the group examine whether intermodal transportation should continue to grow and why; who the players might be in the future of intermodal transportation; and the potential roles of the federal and state governments, carriers, and shippers. Members of the audience suggested several other topics for discussion, including the relationship between intermodal systems and intelligent vehicle-highway systems (IVHS).

Discussion

A broad cross section of participants from the trucking industry, the federal government, and the academic community discussed intermodal operations in the present and future. Although some participants argued for a broader definition of intermodal transportation, the workshop discussion focused on truck-rail movement, access by rail or truck to ports, and, to a lesser degree, truck access to airports. Participants explored the public policy implications of intermodal transportation for governmental organizations at the local, state, metropolitan planning organization (MPO), and federal levels and the implications of intermodal transportation for issues ranging from air quality to regional economic development to the national infrastructure.

Key Issues

The first major issue addressed by the group was continued growth of intermodal transportation. Group members listed a number of potential societal benefits of intermodal transport, ranging from reductions in emissions and congestion to preservation of jobs and infrastructure. A representative of the trucking industry urged that participants emphasize the concrete, practical benefits of intermodal transportation in areas such as cost and quality rather than vague societal benefits.

The discussion then turned to what became a central theme: lack of information about intermodal transportation on the part of policy makers. Because so few comprehensive data exist on the movement of freight, policy makers run a dual risk: overemphasizing intermodal

transportation as a panacea for problems such as congestion and, at the same time, ignoring the pressing realities of freight and urban goods movement and opportunities for improvement.

Group members spent much time exploring the interaction of intermodal transportation with IVHS, particularly automatic vehicle identification. Participants involved with the IVHS program believed that the mechanisms for this interaction—through the commercial vehicle operations element of IVHS—are already in place. A representative from the trucking industry commented that the use of these technologies to increase user fees on motor carriers is a disincentive from the perspective of the trucking industry.

Recommendations

There was general consensus among group members that any future developments and growth in intermodal transportation should be primarily market-driven. However, it was recognized that states or metropolitan areas may find that regional benefits justify actions to alter market outcomes, such as investment or other intervention in the freight transportation system. ISTEA placed considerable authority and responsibility on states and MPOs. Many participants complained that these agencies often have insufficient information and inadequate understanding of freight transportation to effectively deal with this area. Education about freight transportation issues must be provided by the federal government in partnership with private industry. A particularly important role for MPOs and others will involve monitoring the health of freight transportation as seen by shippers and carriers. There was some feeling that the proper role of government was to help integrate systems on the local, national, and international levels.

There was consensus among session participants that a better understanding of intermodal and other types of freight transportation will only occur when data collection activities more accurately reflect the breadth and scope of freight movement in the United States.

Ensuring Free and Efficient Traffic Movement—Harmonization of International Requirements

David G. De Carme, *U.S. Department of Transportation*

David De Carme opened the workshop by saying that it was intended to discuss the requirements for a seamless transportation system across international boundaries. He said that barriers to cross-border transportation have always hindered harmonization efforts and noted that today's paradigm shift in circumstances around the world may make the 1990s a better time to create harmonization.

Discussion

It was pointed out that harmonization of international requirements is not a new idea and that, intuitively, such harmonization should produce a more efficient and cost-effective trading environment. Despite this appeal, progress toward greater international harmonization of regulations, standards, and requirements has been slow and erratic.

Reasons for the slow pace of progress in this area were acknowledged to be many and included government protectionism, pressure of powerful special interests, perceived threats to sovereignty, and the desire to preserve high standards of safety.

The worldwide movement to more open trade and, particularly, NAFTA have renewed interest in finding ways to achieve greater harmonization—but fundamental barriers remain. In general, the group agreed that even though both technical and economic issues inhibit the harmonization of international requirements, the economic issues are much more difficult to resolve than the technical ones.

Workshop participants identified the following areas as most contributing to a lack of free and efficient traffic movement:

- National imperative to insure a level economic playing field in a free trade environment (i.e., ensuring that opening of a border does not provide a competitive advantage for one party that creates economic or political hardship for the other),
- Excessive paperwork requirements for import and export of products,
- Insufficient use of state-of-the-art technology for processing international shipments,
- Multiple and diverse state and provincial requirements,
- Widespread ignorance among industry and local and regional officials of regulatory requirements and their justification,

- A lack of trust between the public and private sectors, and
- Insufficient participation of shipping interests in the design of transportation vehicles and subsystems.

Recommendations

Although there was little consensus among the participants regarding effective ways of dealing with these issues, the following was suggested:

- More investment in advanced automation equipment for processing of freight across national borders,
- Creation of a partnership between transportation companies and shippers before investment in transportation vehicles to ensure the use of vehicles that handle specific cargoes most efficiently,
- Zero-based review of all regulatory requirements,
- Better (and perhaps broader) definition of federal preemption authority over diverse state requirements, and
- More extensive public information and education campaign to provide information on existing regulations and their justification.

EFFICIENT, SAFE, AND ACCEPTABLE TRUCK DESIGNS AND CONFIGURATIONS

Keynote Address

John R. Horne, *Navistar International Transportation Corporation*

As John Horne read the objectives of this symposium, a couple of thoughts came to his mind. The objectives were basically: one, review the current operation and technology trends and explore potential development in these areas that could impact motor carrier transportation as we move into the 21st century; and two, debate and disseminate contemporary research findings and foster effective cross-disciplinary interaction in practical areas such as logistics and goods distribution, truck designs for efficiency, safety, driver and public acceptability, and environmental compatibility.

These are excellent objectives. Horne read a book in the early 1960s called *Excellence in Engineering*. It outlined how scientists develop knowledge for knowledge's sake and engineers use knowledge to solve business problems for the good of people. Horne is pleased to see that this symposium is focused on solving society's problems through the application of knowledge.

His second thought was that the only true measure of our success is what the customer believes—meaning, is it a success in the market? If not, we probably just developed more knowledge—we didn't solve anyone's problem.

The importance of commercial vehicles in our society creates a need for many public- and private-sector organizations to work together. And today we enjoy a relatively close, cooperative working relationship between various government and industry organizations.

A recent example of this partnership is the Highway/Commercial Vehicle Interface Project. About a dozen key public and private organizations, including truck manufacturers, highway engineers and several commercial vehicle user organizations, are working together to find ways to better design trucks and highways. This type of opportunity to let each side know where the other is coming from can only lead to better understanding and increased cooperation between the groups.

Specifically, Horne talked about four things: (a) operating performance, (b) environmental awareness, (c) improved safety, and (d) a North American free trade environment.

Operating Performance

If we look at the progress made in operating performance, we find that 12 to 15 years ago, fleets were realizing fuel economy performance of 2.13 km/L (5 mpg) at gross weights of 32 688 kg

(72,000 lb) and at a speed of only 88.55 km/hr (55 mph). Today, the best fleets realize almost 2.98 km/L (7 mpg) at gross weights of 36 320 kg (80,000 lb), with speed control at 96.6 to 104.65 km/hr (60 to 65 mph). This represents a 40 percent improvement in fuel economy over the last 12 to 15 years, and an even more impressive 70 percent improvement in the ton-miles traveled per unit of fuel.

One of the reasons for this improved operating performance is a better truck design. Today's trucks are more aerodynamic. They have sloped hoods, full-roof fairings, cab extenders, fuel tank skirts, and aero bumpers. Tires have gone from bias to radial with continuous improvements in compounds and construction. Engines have gone from mechanical to fully electronic. And drivelines today have lower overall drive ratios and vehicle speed limit controls.

Today's trucks are also more durable—they're built to last longer. We see fleets that run their trucks for 805 000 to 1 368 500 km (500,000 to 850,000 mi) or more. That was unheard of only a few years ago.

However, our customers are always looking for new ways to increase their operating performance and productivity. One new way is intermodal transportation, which moves freight by a combination of road and rail. Right now, it's a $6 billion/year industry and who knows how big it could grow.

Before touching on some other issues that involve similar cooperative efforts, let's take a look at where the industry has been. In the past, truck manufacturers decided what the customer wanted and then designed and manufactured it. Today, no manufacturer in the world can continue to operate this way and expect to stay in business.

We recognize that our customers require vehicle specifications that meet their particular vocational needs. That's why we must work with customers and suppliers to develop products that meet specific customer needs—not just the needs of our engineers and product planners.

What will this mean to the truck industry? We don't know the ultimate impact that intermodal transportation will have. We'll be prepared to work closely with customers to address the many issues it brings. At the same time, we'll continue to find new ways to increase operating efficiencies. Ideas like integrated engineering between truck tractors and trailers will come into play. Other new areas of technology, such as IVHS, or intelligent vehicle-highway systems, will also be developed.

Environmental Awareness

In the area of environmental awareness, our industry has already made major strides. As fuel economy for heavy-duty trucks has improved there has also been a simultaneous improvement in emission levels for heavy-duty truck engines.

When regulators forced us to clean them up, we cried wolf and said it couldn't be done. But we did it. And we found that contrary to our concerns and objections, engine fuel economy and durability improved significantly as exhaust emissions were reduced. Since then, diesel manufacturers have taken a proactive role to work with regulators and others in the industry to develop new diesel engine technologies and strong alternative fuel programs.

The progress has been remarkable. Today's engines represent a 75 percent reduction in particulates, and a 67 percent reduction in nitrous oxide from pre-1988 levels. And the 1994 engines will be virtually *smokeless* under all operating conditions.

Improved Safety

Safety has always been an issue of concern for our industry. And compliance with safety regulations are top priorities in vehicle design. For example, the number of truck driver fatalities has dropped 50 percent over the last decade. One reason for this improvement is truck drivers' increased use of restraint systems provided by heavy truck manufacturers.

In recent years, Navistar and other heavy truck manufacturers have voluntarily installed three-point shoulder belts as a standard feature in all vehicles. As a result, belt usage by drivers has increased to more than 50 percent in that time.

Also, overall truck safety has improved. According to a recent *New York Times* article, the number of fatal truck accidents dropped 17 percent between 1981 and 1991, while at the same time, the total miles traveled by trucks rose almost 39 percent.

We're also trying to make our trucks safer by offering antilock brakes. ABS minimizes jackknifing and increases the stability of the tractor-trailer.

Driver fatigue is a high-priority issue. Several studies have shown driver fatigue to be the primary cause of fatal accidents. Cooperative government and industry efforts suggest that there might be ways to combat driver fatigue. For example, a mechanism such as an on-board electronic system could monitor driver fatigue and warn drivers of drowsiness levels that could lead to falling asleep behind the wheel.

NAFTA

Finally, Horne mentioned one other important issue that he said will require the support of all constituencies: NAFTA, or the North American Free Trade Agreement. The question is no longer "Will it happen?" but "When" and maybe "How?"

North American free trade will be a great opportunity for those who get involved today. Approximately 80 percent of North American medium and heavy trucks are manufactured and sold in the United States. The remaining 20 percent are split fairly evenly between Canada and Mexico. But the populations and growth potential may cause this to shift as all North America develops together.

How do all of the issues mentioned affect this group? Horne believes that opportunities like this week's symposium allow the public and private sectors to develop stronger partnerships to make even more progress on all of these issues he mentioned. Horne challenges this group and the industry to be even more proactive than we have been in the past. We must work together to be part of the solutions.

Linking Truck Design to Public and Private Life-Cycle Costs

Robert D. Ervin, *University of Michigan*

Heavy-duty vehicles are purchased according to the buyer's specifications and are subjected to a very long and intense service life. Correspondingly, the truck buyer and subsequent owners, as well as the motoring public, must find the as-built vehicle acceptable for a long time and over many miles of operation. In the course of its extended use, the design and configuration of each heavy vehicle will objectively affect its acceptability in terms of the life-cycle costs incurred by both the truck operator and the public. This paper will address the issue of private and public life-cycle costs as they are linked to the design specifications on which the vehicle, itself, was purchased. It is recognized that trucks, tractors, and trailers are purchased individually and that each vehicle will pose costs that trace ultimately to designs that have been specified extensively by the buyer.

Private costs, of course, will be borne by those who own or operate the truck. To understand why trucks are configured and equipped as they are, one must first recognize the natural economic mechanism that promotes truck design features that help the truck owner manage costs. Since the owner is making a business decision when buying the vehicle, the truck specification obviously tilts toward design features and configuration variables that will maximize the return on investment. Accordingly, components and features that do not square with financial payback to this business generally are not ordered, unless they are mandated by law.

Because trucking services do not add value to the shipped product, as far as the end consumer is concerned, pressures to cut trucking costs are continual. Although new service innovations are beginning to differentiate markedly one trucking operation from the next, for-hire trucking has traditionally been a commodity service, with fierce competition pitting large fleets against very small operators or even owners of single trucks. Ultimately the competitive pressures ensure that the design and configuration of the vehicle reflect the economic demands of shippers—the customers of truck operators—to receive reliable cartage services at minimum freight rates. Even in the private trucking sector, where a company operates trucks to meet its own hauling needs, competitive markets for the end product serve to put the squeeze on trucking-related costs.

When the truck purchase is rationalized against these pressures, it is obvious that the truck will become specified in a way that places the premium on productivity and efficiency. Additional components or design features that are not needed for satisfying the premium goals appear on the truck only if required by regulation, union contract, or a specific policy of the

purchaser based on, say, company image or some higher operating ideology. Thus the private costs, especially those that will be incurred early in the truck's life cycle, will be reflected directly in the specifications on vehicle design due to the simple economics of trucking businesses.

On the other hand, only limited mechanisms are in place to ensure that the vehicle is designed and configured in such a way as to contain public costs. Such costs are incurred only indirectly by the public, by means of negative outcomes that include the following:

- The pollution of air with less-than-pure exhaust emissions,
- Deterioration of the public roadway due to truck loading,
- Energy consumption by trucks, with its corresponding impact on our national energy security and the production of carbon dioxide and other "greenhouse gases," and
- Truck-involved crash damage and injury to other road users.

Of course, various regulations and taxing mechanisms have been set up for containing differing aspects of public cost arising from trucking. Nevertheless, certain truck-induced costs continue to be borne by the citizenry without corresponding compensation or mitigation, although these costs may be addressed practicably through vehicle design and configuration. No private incentive exists for covering these costs, so there is little reason to expect that the uncompensated public costs will be considered without a public intervention of some kind.

Furthermore, looking forward from 1993, the political climate is one with a strong national concern to minimize governmental burden on industry, so additional federal standards on truck design and configuration may be few in number and relatively timid in their content. If this is true, an approach that is more subtle than the blunt instrument of federal standards is needed. This paper intends to rationalize the need for innovative methods that can ensure adoption of truck designs and configurations that suitably manage both public and private life-cycle costs within a politically realizable framework.

Before these public cost issues are considered directly, a brief discussion of the truck-user industry will be presented. This section of the paper will establish the scope of the industry and introduce the process by which new trucks are specified and purchased. These considerations show that because the industry as a whole is highly diverse, the designs of heavy trucks are prescribed to a remarkable degree of detail by each individual purchaser, reflecting only the purchaser's economics unless some other constraint holds sway. Once specified and built, the typical heavy truck lasts such a long time and accrues so many miles that the accumulated public cost attributable to each individual vehicle can be great.

The four categories of public cost indicated earlier will be addressed in the light of the public's exposure to each truck, however designed, over its service life. Differing levels of discussion will be devoted in each category, with lesser emphasis on the emissions and highway damage costs than on energy consumption and truck crashes.

The issues of exhaust emissions and highway damage are seen as genuine public concerns that are already receiving a high, and perhaps adequate, level of attention. Because the public concerns are well aligned with the trucker's desire to cut fuel expenses, further intervention by the public sector may not be warranted. Indeed, historical data on the specification and purchase of energy-saving options on new trucks will show that truck design is unquestionably being driven to account for the private-side expenses on fuel. Whether this compensatory action is in adequate proportion to the public burden is less clear.

With truck-involved crashes, however, it appears that costs borne by the public are large and more or less uncoupled from the economic mechanisms that bear on the truck operator. Furthermore, certain innovations in truck safety design may be achievable at an incremental private cost that is low relative to the public benefit. This observation is pursued in the final section of the paper by means of a proposed process for allowing new truck configurations that satisfy more productive size and weight limits only as a "package deal," with new safety and, say, highway-loading requirements attached. It is thus suggested that there may be a politically practicable approach to implementing truck designs that better manage public as well as private costs.

Industry Sketch

More than 100,000 fleets operate combination unit trucks in the United States, of which more than 80 percent own five or fewer trucks (*1*). Thus, a huge number of individual companies are involved, each having its own operating practices and perspectives on the vehicle equipment that it requires. The vehicles are used over a wide range of hauling services: nearly a third operate on a for-hire basis and the rest are more or less dedicated to supporting a private vocational business such as manufacturing, agriculture, and construction (*2*). The diversity of hauling missions results in the distribution of heavy vehicles over the road system with highly differing loading conditions, mileage accumulations, road type selection, day versus night operations, and so forth.

The largest segment of heavy hauling is accomplished in five-axle tractor semitrailers, a vehicle group whose total tractor population in 1987 has been estimated at 706,000 vehicles (*3*). These power units were manufactured generally in the Class 8 weight range under essentially seven brand names, whose respective 1991 market shares are given here (*4*):

Manufacturer	*Market Share (%)*
Ford	9
Freightliner	23
Kenworth	12
Mack	11
Navistar	23
Peterbilt	10
Volvo GM	12

The total number of sales in this heaviest class in 1991 was 99,000 units (a volume depressed by 20 percent or so below average by the recession in the early 1990s). In almost all such sales, the product will have been marketed according to the process outlined in the following.

Heavy Truck Marketing

The heavy-duty truck is purchased by means of a buyer's order that includes a great specificity regarding the desired equipment. The order sheet will typically include selections from hundreds of optional specifications for, say, a road tractor. In each specification, the buyer may choose from a variety of alternatives in selecting individual components—frames, axles, springs, brakes, engines, transmissions, instruments, seating, fuel tanks, batteries, and on and on. The price list from one large manufacturer, Navistar (*5*), shows that a certain conventional-cab model is ordered by means of a "line setting ticket" that specifies 88 items, with options selected from among 21 seat options, 11 mirror selections, 13 fuel tanks, 18 rear axles, 11 rear suspension assemblies, and 51 diesel engine selections, each matched for compatibility against a matrix of 55 optional transmissions.

For the power train, the choices that have traditionally been available in terms of hardware are now vastly expanded through the tailored setting of programmable engine control software. And the trend is toward more and more specificity and selectability on the part of purchaser.

In short, when it comes to truck buying, the customer has a high degree of authority and latitude in selecting the equipment. Correspondingly, the truck manufacturer exercises much less assertiveness in pushing certain equipment packages on the buyer than is seen in the marketing of passenger cars. In the vast majority of medium and heavy truck sales, there is simply a "pull-marketing" relationship between the buyer and maker of the truck: very little is bundled into inseparable groups of optional components. This way, what the truck buyer doesn't want, the truck buyer doesn't get. This principle was confirmed in recent years by certain European manufacturers that attempted to introduce highly integrated vehicle pack-

ages into the medium and heavy truck market in North America and met with very little success.

The traditional assumption that underlies the remarkable level of specificity in the United States is that the differences that distinguish one trucking operation from the next must be reflected in detailed truck specifications if the operation is to be both productive and efficient. The tradition of detailed specification yields a system that is maximally responsive to the truck buyers' desires while slowing truck innovation to the buyers' pace of technical awareness and confidence. And the buyer is typically tilted toward conservatism, as well, in selecting unproven features since the vehicle will be used intensively over a very long service life: the buyer knows that specification mistakes can be costly.

If innovative features are to be sold on original equipment manufacturer (OEM) trucks, the crucial interactions will occur between potential truck buyers and (a) component salespersons who visit in advance of vehicle ordering to prompt the selection of proprietary items when the truck order is placed, and (b) the OEM salesperson who facilitates the ordering itself. If the vehicle is to incorporate an innovative item, the truck buyer must have been persuaded to take it through one of these two exchanges or through some other input. But if the functionality of the item is unrecognized, unfamiliar, or of marginal cost-justification in the buyer's mind, the chances of its inclusion on the order list will be low.

Truck Service Life

Perhaps the single most valued quality in any piece of truck equipment is durability, that is, the uninterrupted delivery of the needed functions over a long service life, given the specific hauling mission. As an indicator of the intensity of usage that is expected, Figure 1 shows the average annual mileage to which Class 8 tractors are subjected over a typical 17-year service life. [The values were obtained by computing average miles traveled during 1987 by vehicles whose age was also reported in the 1987 *Truck Inventory and Use Survey* by the Census Bureau (*3*). The data have been truncated to an effective limit lifetime of 17 years, estimating the diminished use

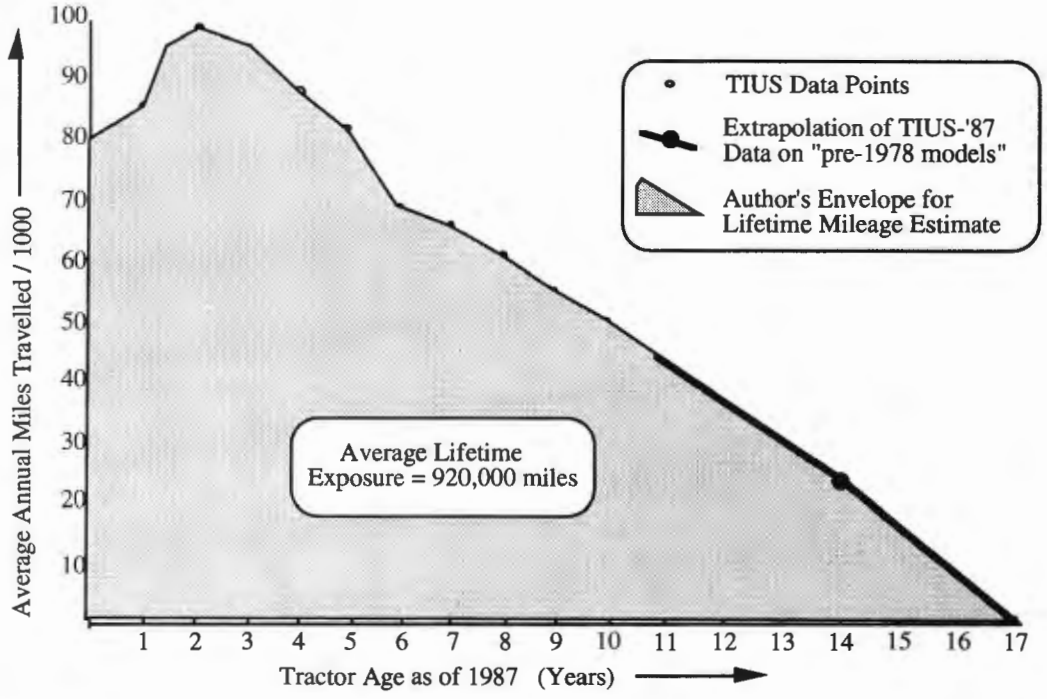

FIGURE 1 Average annual miles traveled by three-axle tractors in combination with two-axle semitrailers, as function of tractor age.

that continues with vehicles even older than 17.] The integral under this curve reveals a typical lifetime exposure of 920,000 mi.

Casual information from the industry suggests that the original purchaser is seldom the same party operating the vehicle at the end of a 17-year service life. Thus, the purchase specifications are obviously tilted to ensure highly efficient and reliable performance during the early years of service, when typical annual mileages are 80,000 to 90,000 mi/year. Clearly, the vehicle is specified to ensure high satisfaction for the original buyer as well as reasonable resale value when it is transferred to other users.

The service-life data show that the modern vehicle is so durable that it can sustain high-mileage use over a long string of years. This observation, suggesting that the American road system will be exposed to the as-specified vehicle for nearly 1 million mi of operation, is clearly central to the issue of public cost due to trucks and to the significance of an OEM design. Indeed, only after about 15 years does the annual mileage of an average heavy tractor drop into the range of 10,000 to 15,000 mi/yr to which the typical new automobile is exposed. Accordingly, the public costs that are attributable to each individual truck are scaled according to the lifetime exposure of the vehicle and are thus magnified in the case of the heaviest trucks and tractors.

Primary Sources of Public Cost Due to Trucking

The four previously identified sources of public cost due to trucking will be discussed in turn. Each presents a different context by which public costs can be managed if some means is found to control truck design, as follows:

- For exhaust emissions, the locus of design for controlling public costs is in the combustion and gas-handling technology of clean burning;
- For highway damage, it is through axle spacing, axle and tire loading, and perhaps suspension dynamics;
- For energy consumption, it is in combustion efficiency and parasitic loss mechanisms;
- For traffic crashes, it is broadly distributed among dynamic control qualities, conspicuity of the vehicle at night, splash and spray generation, load securement mechanisms, ride qualities affecting driver fatigue propensity, structures that determine aggressivity of the truck during impact, and other items.

Exhaust Emissions

The Environmental Protection Agency (EPA) has established a schedule of increasingly demanding requirements for the emission containment of heavy-duty diesel engines. In fact, U.S. standards on diesel emissions are the most stringent in the world. Clearly, a governmental regulation was necessary in this case since truck buyers have no natural economic incentive to specify a low-emission engine, per se. Thus, some public-sector role is required if the environmental agenda is to advance.

The EPA requirements cover a broad spectrum of pollutants. Table 1 indicates that a continued tightening of regulations on heavy diesel truck engines has been under way since 1974, with the most recent round of improvements dwelling on oxides of nitrogen and the particulates that are peculiar to diesel combustion (6).

Given that diesel emissions have been the subject of a vigorous process of federal regulation, it is apparent that the public costs of environmental damage have been recognized in this case and that countermeasures have been adopted. The needed corrections have been effected almost entirely by the manufacturers of heavy diesels, some of which are also OEM truck makers. To the degree that a modern, electronically controlled diesel retains a low-emission performance throughout the lifetime of the chassis, with overhauls, the EPA standard has

TABLE 1 New-Vehicle Emission Standards, Heavy-Duty Diesels (*6*)

Year	Hydrocarbons (g/bhp-hr)	Carbon Monoxide (g/bhp-hr)	Oxides of Nitrogen (g/bhp-hr)	Hydrocarbons and NOs (g/bhp-hr)	Particulates (g/bhp-hr)	Smoke (% opacity)
1970–1973	—	—	—	—	—	Accel = 40 Lug = 20
1974–1978	—	40	—	16	—	Accel = 20 Lug = 15 Peak = 50
1979–1983	1.5	25	—	10	—	Accel = 20 Lug = 15 Peak = 50
1984	1.5 (A test) 1.3 (B test)	25 (A test) 15.5 (B test)	— 10.7 (B test)	10 (A test)	—	Accel = 20 Lug = 15 Peak = 50
1985–1987	1.3	15.5	10.7	—	—	Accel = 20 Lug = 15 Peak = 50
1988–1990	1.3	15.5	6	—	0.60	Accel = 20 Lug = 15 Peak = 50
1991–1993	1.3	15.5	5	—	0.25	Accel = 20 Lug = 15 Peak = 50
1994–1997	1.3	15.5	5	—	0.10	Accel = 20 Lug = 15 Peak = 50
1998	1.3	15	4	—	0.10	Accel = 20 Lug = 15 Peak = 50

constituted a highly effective means of controlling the associated public cost, despite the long mileage exposure of the vehicles involved. The extent to which the typical modern engine will, in fact, deliver low-emission performance over its service life, however, is unknown. Furthermore, the author has not sought to establish how the cost of regulatory compliance compares with the public benefit of reduced rates of pollution.

Highway Damage

It is well recognized that the deterioration of highway pavement and bridge structures is strongly dependent on truck use of the roadway. In particular, there is a profound, approximately fourth-power relationship between truck axle load and the rate of pavement break-up (*7–9*). This aspect of truck-induced public cost has figured prominently in the taxation of trucks and appears implicitly in cost allocation approaches to highway financing. Namely, states have, with federal guidance (*10*), established graduated scales of road use and licensing taxes that differentiate among vehicle types on the basis of the perceived highway damage and ancillary highway costs that each vehicle imposes. Although a continuing debate ebbs and flows on the extent to which truck-induced highway costs are recovered by road agencies, one can assert that costs are being recovered to the degree supported by the overall political context (noting that the trucking community normally represents its interests vigorously in each state's legislative debate.)

To give a first-order estimate of the magnitude of tax revenue generated by heavy trucks to support highways, nationwide, a simple computation can be made on the basis of average tax rates and average vehicle cost and use. Diesel fuel is taxed at a federal rate of $0.201/gal and an average state rate of $0.18/gal (*11*). Assuming that the 1 million Class 7 and 8 trucks (*1*) each travel an average of 50,000 mi/year (*3*) at an estimated average fuel consumption rate of 6 mi/gal, the total annual revenue from fuel tax on heavy-duty vehicles is on the order of $3.2 billion. Annual federal tax on the vehicle itself is about $400/unit, depending on gross vehicle weight. A 12 percent excise tax is applied to the retail price of newly manufactured trucks and trailers, and an excise tax of about $15 is imposed on each new truck tire. It is estimated that these vehicle-based federal taxes total approximately $2.5 billion/year. In addition, states impose individual registration fees, surcharges on fines for violations, and weight-distance taxes in a few cases. Altogether, the collections from the heavy end of the truck population amount to approximately $6 billion, or 11 percent of the $55 billion in state and federal revenue collected from highway users. Out of the total revenue, some $46 billion in state and federal funds is spent on capital outlay, maintenance, administration, and law enforcement on the nation's highways (*11*). Another 25 percent or so is spent from receipts collected by county and municipal governments.

The cost allocation issue addresses the question of whether the amount that heavy vehicle owners pay compensates the public for the net costs associated explicitly with heavy truck use of the road infrastructure. Although this question is exceedingly difficult to answer in a comprehensive manner, it is apparent that the total highway program in the United States is substantially underfunded, overall, and that greater tax revenues must be generated in the future to suitably maintain its sprawling network of bridges and highways. Being sobered by the many vagaries of the cost allocation question, this author chooses to address only the mechanistic link between road wear and tear and the design of the truck itself.

It is generally believed that the first-order road damage factors derive only from axle load and the spacing between loaded axles as addressed in bridge formula calculations. Neither of these poses a very clear "design issue" relative to trucks since the only design characteristic in question involves the geometric layout of the vehicle configuration—in particular, the axle placement. Research also suggests that truck suspension is instrumental in determining transient load peaks that locally aggravate pavement deterioration, especially downstream of bumps and other surface faults (*9,12*). These results tend to argue for well-damped suspensions having relatively low vertical stiffness levels. Air suspensions and some of the more carefully designed spring suspensions are favored in this regard, but no requirements regarding suspension type have been imposed in the United States.

One innovative approach to minimizing truck-induced road damage was proposed by former FHWA Administrator Frank Turner (*13*). The Turner Proposal was to allow bigger, more productive truck configurations outfitted with additional axles that carry loads below current levels, thus accruing a large reduction in pavement cost that exceeds the value of an accompanying hike in bridge-related costs. The inherent attractiveness of the Turner Proposal is that a net public savings of approximately $326 million/year in highway costs is obtained through a policy that also offers a savings of approximately $2 billion/year in truck operating costs. TRB analysis clearly shows a "win-win" situation, where the savings to truck operators derive from the higher payloads that could be carried on an individual vehicle.

It appears that the for-hire trucking industry does not generally favor the Turner Proposal, however, since the transition to new vehicles requires a surge in capital investment while competitive pressures on freight rates will, in the long run, eliminate the cost advantages accruing to any individual trucking company. The macroeconomics look great, but the micro view taken by a for-hire trucking operation is not favorable. (An exception to the "micro" stalemate has been seen, however, when the for-hire operators have acted very quickly during a transition in truck size and weight allowance, buying new equipment immediately and striving to grab market share through the new productivity advantage before their competitors could catch up.)

Any shipper of freight, and thus all companies in the private trucking sector, should favor a proposal such as Turner's if it truly offers a net reduction in shipping costs. The apparent failure

of the entire manufacturing community, and the private trucking segment in particular, to rally behind the Turner Proposal is, then, something of a puzzle. A suggested explanation is that the people who run the trucking divisions of large private product and service corporations are not, themselves, engaged in the strategic direction of these companies and thus are not well tuned to the company's long-term concern with global competition. Thus, when representing their corporate interest through, say, the National Private Truck Council, they may not readily concern themselves with the more esoteric long-term issues that stand to affect shipping costs across the board but instead are focused on the myriad tactical issues that face fleet operations. Nevertheless, the concept of a quid pro quo approach toward balancing public and private costs via truck design, as in the Turner Proposal, should be of interest to all private parties concerned with reducing the cost of freight movement; at the same time the concept offers a means to recover publicly borne trucking costs. This concept will be revisited on behalf of generic improvements later in this paper.

Energy Consumption

Considerable improvements in the fuel economy of heavy-duty vehicles have been obtained since the mid-1970s, beginning with buyer-specified components that helped to reduce parasitic losses and the selection of diesel engines offering more fuel-efficient operation. In this case, the perceived public cost associated with fuel use is expressed in terms of the level of national dependency on foreign oil importation (the so-called energy security issue), the release of greenhouse gases, and the sheer volume of toxic pollutants as it results from total gallons consumed.

But the public concern for these outcomes happens to line up with the obvious private concern of truck operators to limit what they pay for the fuel itself. When fuel prices more than doubled in 1974 and 1975, truck owners felt the stimulus right away. Thus, a truck owner's enhanced desire for a high level of fuel economy, measured in miles per gallon consumed by the truck, was squarely in line with the public desire as well. Whether today's fuel prices reflect the extent of public costs by attaining the needed level of private incentive is another question. Clearly, the public costs are not driven to zero through this mechanism, but they should certainly drop as the extant price of (diesel) fuel rises—albeit with some delay while economy-enhancing products are prepared for market. The progress toward improved energy efficiency in trucking will be reviewed both in terms of the state of achievement and as an example of the natural economic mechanism at work, by which the private costs of trucking tend to cause truck design and configuration to respond to the commercial pressures of the business.

All motor vehicles have seen a dramatic improvement in their fuel economy performance since the oil embargo of 1973. Passenger cars in the United States made improvements under the strong prod of the Corporate Average Fuel Economy (CAFE) rules, but the heavy truck sector did so largely on its own, with manufacturers collaborating through the Voluntary Truck and Bus Fuel Economy Program (*14*). Industry experts have told the author that the fuel economy performance of a typically loaded tractor semitrailer rose from about 3.5 mi/gal in 1973 to nearly 7 mi/gal in 1990. Evidence of the natural economics of fuel conservation is given in Figure 2, showing that heavy-duty trucks began to be specified with a strong concern for fuel economy soon after the oil embargo.

The data show that the specification of variable fan drives, for example, as a component installed on Class 8 trucks and tractors went from 4 to 96 percent of sales in 8 years (admittedly with a boost in 1978 from an EPA regulation that helped to cost justify the thermatic fan.) Radial tires, already popular in Europe in the early 1970s, gained rapidly in popularity because of both the remarkably lower rolling resistance (and thus improved fuel economy) and the better treadwear performance and recap ability. Aero cab shields showed a more modest rate of adoption, presumably because of some early structural problems and the somewhat reduced overall market, since they are not helpful when hauling flatbeds and most tank-style semitrailers.

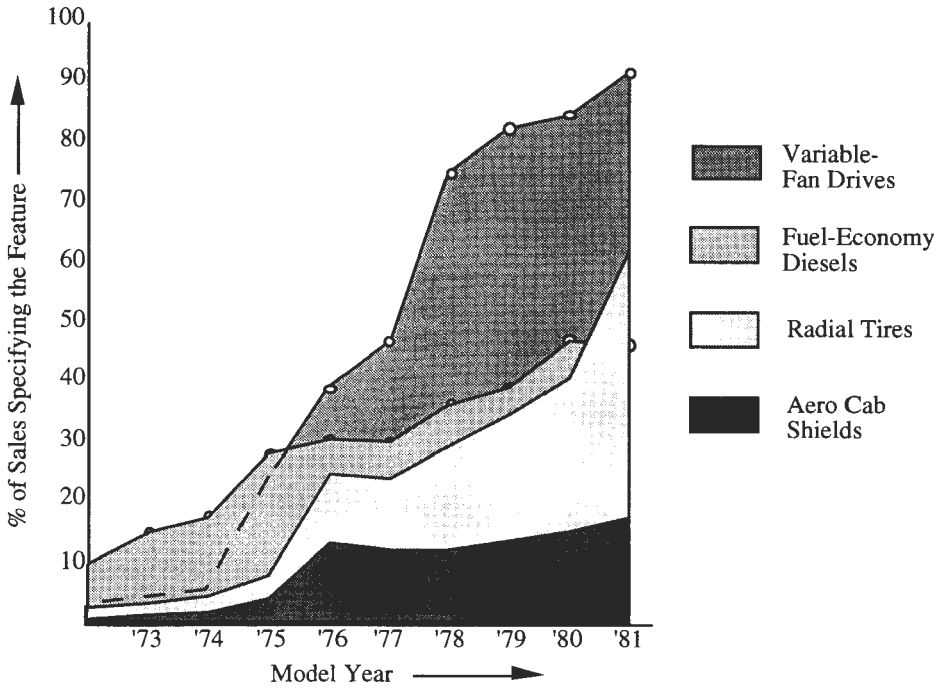

FIGURE 2 Adoption of design improvements versus model year (*14*).

The rapid rise in adoption of energy-enhancing features reflects the combined influence of the natural predisposition of truck buyers to contain rising fuel costs, as discussed, and the accelerated action by truck makers who were concerned about both meeting customer needs and avoiding a CAFE-equivalent regulation of their industry. The data make the obvious case that the truck buyer will respond to economic pressures, adopting new truck design elements as required to manage the private costs of trucking. It is clear that truck owners did not specify energy-saving features simply because of some newfound concern about geopolitical risk to the nation. Instead, it made good business sense—and truck owners are in the trucking business. It is elementary economics that wherever private costs arise, private response mechanisms will appear.

An interesting twist on the matter of energy economy is the growing obstacle to trucking posed by urban traffic congestion. To the extent that trucks encounter delay on congested highways, fuel is wasted because of the inefficiencies of shifting up and down the gear range in dense traffic, with the engine operating far from its peak economy regime. Accompanying this form of inefficiency is the much higher private cost of time—that is, the time-cost of the driver, the capital equipment, and the delayed-delivery payload that pose an economic burden calling for a solution, wherever it may be found.

It would appear that the congestion-driven issue plus other time inefficiencies can be addressed by electronics systems yielding automatic vehicle location, mobile communications, and computer-aided dispatch, especially if vehicles can be routed individually in response to real-time traffic information. These functions, enabled by surging advancements in computing, mobile data networks, new satellite facilities, and associated information technology, fall under the rubric of intelligent vehicle-highway systems (IVHS) (*15*). Large truckload fleets and parcel services are beginning to adopt such technology, by way of aftermarket channels rather than the OEM truck maker, at a significant rate (*16*). The intriguing aspect of these innovations is that although they have been first rationalized on the basis of the time-efficiency argument, operators are discovering that wholly new forms of customer service can be offered, thereby differentiating the "intelligent-technology" fleets from their conventional competitors and perhaps re-sorting market shares in the not-too-distant future.

A compelling example of the new services was cited recently by a large truckload operator (*17*). The availability of automatic vehicle location and mobile communications has enabled a central dispatcher to continuously control the routing, and even the destination assignment, for a large group of individual trucks that have been loaded with mixed freight headed for any of a group of warehouses operated by a large national retailer. As inventories develop dynamically across many of the company's facilities, a corresponding dynamic reassignment of each truck has led to a wholesale reduction in the incidence of intermediate stops for partial unloading and reloading. The increasingly common experience of this operator is that of near-optimum, single-stop routing aided by a corresponding loading of trucks at the outset to match the dynamically reroutable logistics of the operation.

The lesson of fleet adoption of IVHS technology, again, will be that the economics of the trucking business will readily attend to minimizing private costs (perhaps with the fortuitous by-product of more competitive services). The public aspect of these developments is that IVHS solutions may reduce the trucking contribution to traffic jams and may support a means of enforcing on-road trucking regulations at reduced public expense. Again, it can be generalized that when truck efficiency is at risk, whether measured in units of time, energy, or any other currency, a natural mechanism will exist that tends to resolve the inefficiency, perhaps helping to contain the associated public cost in the process. To the degree that truck design or equipment helps achieve efficient operations, the industry will tend to press for the cost-beneficial improvements.

Traffic Crashes

Truck crashes impose both private and public costs. Clearly, the truck owner incurs private costs from truck damage repair, liability insurance, workmen's compensation, freight damage, and the alienation of a shipping customer whose payload is wrecked. Public costs deriving from truck crashes are thought to vastly outweigh the private costs to the truck owner, though, and appear to represent a large uncompensated burden over the life of the typical heavy-duty truck.

The entire safety picture, in terms of accident loss per mile of exposure, has steadily improved in the United States, with the total national fatality rate now below 2.0 fatal accidents per 100 million vehicle-mi of travel (100M vmt) (*18*). Taking the latest authoritative figures for truck travel—those collected in 1987 by the Census Bureau (*3*)—a corresponding rate of 6.17 fatal involvements per 100M vmt was seen with 3S2 tractor semitrailer combinations (where this vehicle configuration is chosen simply as a convenient, large-population surrogate for all heavy vehicles) (*19*). It is also recognized that, because of the aggressivity of such vehicles in collisions with passenger vehicles, an average of 1.15 fatal injuries are produced per fatal involvement with tractor semitrailers. [As an aside, it should be acknowledged that a remarkable improvement in the protection of truck occupants has occurred from 1979 through 1991, with the truck occupant fatality rate dropping approximately in half over that period (*20*). Apparently the lion's share of this improvement has derived from a wholesale increase in seat-belt use by truck drivers, although significant upgrades in the crash integrity of cabs and truck fuel systems were made toward the end of the period as well.]

Without going further into the issue of statistical trends—a controversy that becomes readily enmeshed in debate over the applicable exposure figures—it is useful to consider the public cost implications of the national truck accident experience, taking the gross numbers from 1987 as representative. The author suggests that a likely change of, say, 10 or 15 percent in truck accident rates since 1987, up or down, would be immaterial to the point of the following observations and thus a further exploration of the statistical base of information is not merited here.

Focusing on the public cost of truck crashes, it is helpful first to simplify the problem by integrating the accident rate across the lifetime mileage traveled by the typical three-axle tractor; doing so obtains a life-cycle accident count attributable to one individual vehicle in this class. Then, using federal rates for computing the economic cost of accidents, this figure can be

converted into a life-cycle public cost due to traffic crashes involving this vehicle. This public-side cost may be compared with an estimate of the private costs that are incurred over the same life cycle by the private operator of such a truck combination. Recognizing the private costs as business expenses, the question of covering the public loss is an issue in cost-recovery policy.

If 6.17 fatal involvements are incurred in each 100M vmt units of exposure, then (6.17/100M) multiplied by the lifetime exposure of the typical three-axle tractor—920,000 mi—gives the lifetime fatal-involvement risk for one vehicle of this type. The result is 0.057 fatal involvements per tractor lifetime, or 1 for every 18 vehicles manufactured. The significance of this astonishing result can be portrayed in a mental picture: Imagine standing at the end of a heavy vehicle assembly line and watching newly manufactured vehicles exiting the plant. Consider the question, "If this is our last chance to alter the equipment, is there anything reasonable that can be done to each batch of 18 vehicles to minimize the risk of an otherwise inevitable fatal crash that will involve one of them?" On a per-vehicle basis, the lifetime concentration of risk is startling.

The dollar magnitude of public crash costs has been studied by a number of investigators (*21–23*). Although compelling arguments are made for both economic and so-called comprehensive forms of costing, only the smaller-cost federal economic approach will be employed for illustrations presented here. The most recent evaluations conducted by NHTSA show an annual national cost of $137.5 billion accruing from the 1990 total of 44,531 fatalities, 5.4 million reported injuries, and 28 million vehicles damaged (*23*). Assuming that heavy truck crashes produce approximately the same proportions of injury and property damage losses per fatality as all accidents, one can simply lump the injury and property costs in with each fatality as a convenient means of computing the cost of operations per fatal accident. This figure comes to a total annual cost of $3.08 million/fatality that is counted (including the pro rata cost of injuries and property damage). If this total is spread across the 18 tractors that will accrue such costs per vehicle lifetime, multiplying also by the 1.15 persons that are actually killed per fatal tractor involvement, the lifetime crash-related cost per three-axle tractor is $197,000.

Clearly, the lion's share of this life-cycle crash cost is borne by the non-trucking public. In crashes involving cars striking combination-unit trucks, for example, the fatality ratio—deaths to car occupants versus deaths to truck occupants—is about 37 to 1 (*2*). It is reasonable to assume that the distribution of injuries and property damage losses is overwhelmingly tilted toward the passenger vehicle, as well. For purposes of discussion, it is assumed that the public bears $180,000, or approximately 90 percent of the cost per crash.

On the private side, the corresponding life-cycle costs associated with purchase and use of a three-axle tractor over 920,000 mi of operation are estimated as follows:

	Cost ($ thousands)
Capital outlay	100
Cost of capital (10 percent for 5 years)	38
Accident costs ($197,000–$180,000)	17
Maintenance costs (8¢/mi)	74
Fuels and lubricants (20¢/mi)	184
Total	413

Accordingly, note that for every three-axle tractor that is built (again, with this vehicle configuration being considered only as an example), $413,000 is paid just to own and operate the equipment over its lifetime while the public contributes an additional $180,000 to cover only the crash-induced costs that are borne publicly. (The author acknowledges that complete comparison of both cost types would require the factoring of a discount rate against a timetable of cost accrual for both cost streams. Unfortunately, such a process in not enabled by data available here.) Whether the public cost of $180,000/tractor lifetime should be viewed as an indirect subsidy of private enterprise (i.e., the trucking industry) or an alternative means by which the public pays for freight services is a philosophical matter. The pressing issue here is

that a $180,000 crash toll is being borne by the citizenry per heavy tractor—how can it be lessened through a cost-effective change in vehicle design and configuration?

Much research has been done to help discover the aspects of truck design that could be improved by way of crash countermeasures. It is not the purpose of this paper to revisit the broad scope of these studies (although the reader is referred to two major government investigations that have given balanced treatment to the overall issue (*1,2*). As an illustration of the path toward more acceptable management of the safety component of life-cycle costs, however, one of the safety countermeasures suggested by the NHTSA investigation will be considered.

The safety agency noted that 75 percent of all fatalities in heavy vehicle accidents involve impacts with another vehicle, of which 68 percent entail strikes against the front portion of the truck. On the proposition that about 44 percent of these front strikes are candidates for resolution by means of a cushioning and underride-preventing bumper on the truck, the data show that such a device would target an accident group amounting to 22 percent of all fatalities involving trucks. In terms of the simplified analysis presented earlier, this target would appear to have a public "worth" of about $40,000 in design improvements on each vehicle, if a fully effective countermeasure were identified.

A downside of a countermeasure of this type, where a weight and length penalty appears unavoidable, is that the hauling capacity of the overall vehicle would diminish unless size and weight regulations were somehow extended in a package form of compensation. Such an observation is central to trucking economics, however, because payload-constraints show directly as constraints on truck revenue per trip. For example, using a typical freight rate of $0.0001/lb-mi, a vehicle that would spend 20 percent of its 920,000 lifetime miles operating right at the maximum allowable loading condition (where a higher tare weight directly reduces the payload weight) suffers a lifetime loss of operating revenue equal to $18/lb of excess tare weight.

If a crash-forgiving bumper weighed 400 lb, for example, $7,200 in operating revenue would be displaced. Noting that $40,000 in public crash costs could be eliminated by a 100 percent effective (400-lb-heavier) front bumper, even a 25 percent level of effectiveness for such a device would appear to yield a cost-justified package—with $10,000 in public savings available to cover the $7,200 in operating loss plus a $2,800 budget for the bumper equipment and its lifetime maintenance costs.

This example has been discussed simply to illustrate the rationale that introduces life-cycle costs into the consideration of truck designs for achieving acceptable safety performance. In the final section, an approach for implementing measures to balance public costs without mandatory standards is briefly outlined.

"Carrot and Stick" Package

The quid pro quo approach suggested in the Turner Proposal, mentioned earlier in the paper, serves as an illustration of a general strategy for managing certain public costs of trucking without mandatory equipment standards. Here this approach will be called the "carrot and stick" package (CSP), reflecting the bundling of *requirements* for equipment that has public value but will not sell on its own (the "stick"), with the *allowance* of a more productive truck configuration—one that is otherwise prevented by existing size and weight constraints (the "carrot"). The premise for using this approach for a public cost issue is that regardless of the public merit or even the best efforts of the OEM truck maker to highlight the feature, an equipment improvement that is not economically attractive to the truck buyer will not be purchased.

Further motivation for such a strategy is seen in a current case in point, shown in Figure 3. It is seen, by way of contrast with the energy-saving trends discussed earlier, that the specification of antilock braking systems (ABS) by the customers of one heavy truck manufacturer have proceeded sluggishly since the systems were introduced in 1987 (*ABS Usage in Class 8 Trucks,*

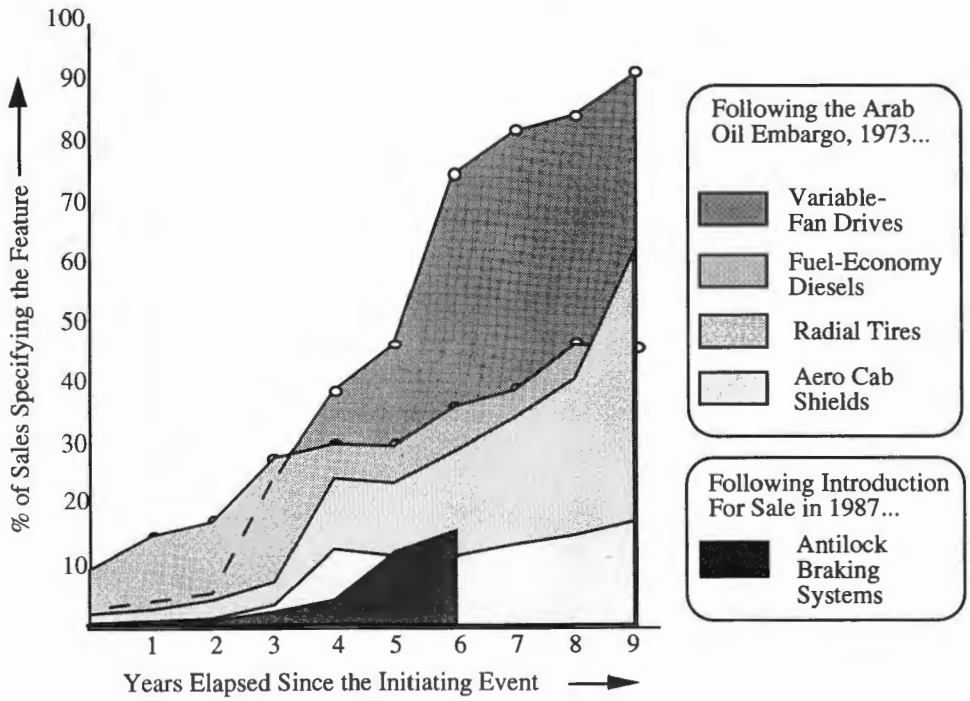

FIGURE 3 Rate of sale penetration by ABS on Class 8 trucks compared with the penetration of fuel economy–enhancing devices.

Model Years 1987–1992, a list of production data on ABS provided to the author by a U.S. truck manufacturer, Dec. 1992.).

The data show that it has taken 6 years for ABS sales to reach a 15 percent selection rate. These data support the theme of this paper: namely, that truck operators will select and specify truck equipment almost exclusively in response to the realized private costs of operation. (It is interesting to note that ABS was also introduced seriously into a number of passenger car models beginning around 1987 and is estimated to have penetrated to 40 percent of all sales by the end of 1992. Safety now appears to sell in the passenger car context where the decision to buy is much less an economic question than one of the personalization of value by each consumer.)

Moreover, it is economically understandable that equipment such as ABS for trucks penetrates the market very slowly, although its additional value for reducing public costs would probably tip the scales strongly in favor of the purchase. Safety equipment such as this is especially difficult to justify, in the truck purchase, for two powerful reasons:

1. Accidents are rare events that are also normally confused by a multitude of contributing factors (such that it is difficult for the truck owner to value an individual countermeasure in terms of safety effectiveness, per se, let alone in terms of the cost/benefit ratio).
2. The largest portion of the accident cost (perhaps 90 percent, as in the author's estimation) is borne by others and thus falls outside of a pragmatic business consideration.

By contrast, truck design improvements on behalf of fuel economy offered obvious benefits because the need following the 1973 oil embargo was inescapable—the increased fuel price was encountered every day—and the entire costs involved were borne by the business itself.

Thus, in the timid regulatory environment that this decade appears to project, it appears appropriate to consider public policies that lead to a managed, competitive dynamic within which the purchase of the safer (or less highway-abusive, or less polluting, etc.) truck is mandatory. Various examples of a CSP approach have been proposed (*13*,*24*) and some have been implemented, notably in Michigan (*25*) and as an interprovincial trucking policy in

Canada (*8*). If this approach is to be applied effectively at the national level in the United States, a methodical process is needed, as given here:

1. The public sector, particularly the U.S. Department of Transportation, must lead in identifying effective equipment improvements that already are, or can readily be, offered for sale on OEM trucks and that arguably ameliorate the public cost incurred over a truck's life cycle.
2. Vehicle manufacturers and suppliers must establish that the equipment can be offered, and the retail prices of such hardware must be estimated.
3. Operators must confirm, or cooperative field testing must demonstrate, that the systems are suitably functional, maintainable, and so forth; operating costs must be estimated.
4. A package of attractive weight or cubic capacity extensions must be identified as tractable from the viewpoint of highway operations and maintenance and inherently attractive for the enhancement of truck productivity.
5. A CSP proposition of requirements and allowances must be defined in terms of distinctive vehicle configurations that stand out so markedly that their identification for enforcing the requirements is straightforward.
6. The business incentive for such productivity enhancements must be analyzed by independent experts on trucking economics, developing the financial part of the equation and calibrating the numerical parameters for size and weight limits so as to make industry adoption of the CSP-defined vehicles competitively unavoidable.
7. Implementation of the North American Free Trade Agreement may suggest that a CSP proposal should also factor in the synergistic influences of Canadian and Mexican road use laws. For example, where Canadian allowances already provide for certain truck configurations carrying larger-than-U.S. payloads, it may be in the United States' interest to consider packages that approximate the same allowances but require new safety equipment and perhaps other additions. If it is imagined that some trucking segments in the United States might delay in implementing CSP vehicles because of hesitancy about capitalizing new equipment, the dynamic of ready-made Canadian (or Mexican) competition might well accelerate the pace of transition to new equipment.
8. On definition of the overall package constraints, a coalition must be built between state, federal, and industrial interests so as to support the needed Congressional legislation. If the reduction in public costs due to trucking are strong and productivity enhancement is high, support from the manufacturing community should be expected in the light of the potential for reducing freight rates and thereby improving the global competitiveness of U.S. products.

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Summaries of Panelists' Comments

Thomas L. Hardeman, *United Parcel Service (retired)*

As a truck buyer, Thomas Hardeman disagreed with two statements in Ervin's paper: "components and features that do not square with financial payback to this business generally are not ordered unless they are mandated by law," and "[a]dditional components or design features that are not needed for satisfying the premium goals appear on the truck only if required by regulation, union contract, or a specific policy of the purchaser based on, say, company image or some higher operating ideology." At United Parcel Service (UPS), he maintained, interest in equipment, safety, infrastructure, and environment goes far beyond what is dictated by regulation or by union contract. Much of its progress has been linked to safety.

Experts report that equipment failure is a factor in fewer than 20 percent of accidents; human error (i.e., error of the driver behind the wheel) is a factor in the remaining 80 percent. Therefore, UPS has stringent training requirements for its drivers, reflecting the commitment of its founders to building its business on public trust. UPS drivers undergo hundreds of hours of training in what are known as the companys "little brown package cars," followed by a thoroughly controlled initial training program of 100 hr of one-on-one training. For the rest of their careers, UPS drivers complete 1 day of training four times a year.

Besides driver safety training, UPS has incorporated the following nonmandated truck safety features into its designs over the years: drop-frame trailers, 444.5-mm (17½-in.) pintle hook height, high-amperage electrical wiring, vented rear shutoff valves, antispray devices, trailer axle settings at 914.4 mm (36 in.) from the rear of the unit, air-actuated trailer pintle hook, fifth-wheel lock guard, direct draw bar pull, and minimal dolly spring free play. Other safety elements incorporated into UPS's safety program include brake timing tests, brake chamber stroke alerts, and radial tires.

Hardeman took issue with several other points in Ervin's paper:

- In contrast to Ervin's suggestion that public safety costs are not connected to the truck owner's costs, Hardeman maintained that the costs are directly related. Operators' insurance costs include payments for hospitals, personal injury, and property damage.
- Truckers also make payments to government entities for damage to public facilities. Hardeman noted that Ervin's paper makes no reference to longer combination vehicles (LCVs), which cause less pavement damage, save fuel, and reduce exposure through fewer trips.

- The paper cited the Environmental Protection Agency (EPA) program as being highly effective in reducing emissions that cause pollution but failed to mention the various state regulations and tests to which truckers are subject. These programs require analysis to assess their effect on the environment relative to the high costs borne by industry in complying.
- Hardeman also questioned the contention that trucks are the major contributing factor to pavement damage; he asserted that there has been no quantified linkage between pavement damage and traffic loading on properly designed pavement. In addition, a state highway study has proven that trucks pay their way; in fact, they pay more than their share on the roads they use regularly. Claims of the damage caused by trucks are often made by competing modes of the transportation industry, according to Hardeman.
- Hardeman recommended the adoption of the recommendations of TRB's *Special Report 225: Truck Weight Limits: Issues and Options*, as opposed to the Turner Proposal, which applies to only a small class of vehicles and would not generate the payback that implementation of *Special Report 225* would. On the other hand, *Special Report 225* offers complete utilization of equipment to be operated within adequate bridge formulas and constraints.
- Finally, Hardeman took issue with Ervin's computation of fatality figures. His calculation for UPS operations indicated 5.2 fatalities per 161 million vehicle-km (100 million vehicle-mi) in 1987 and 3.5 fatalities in 1991, as opposed to Ervin's figure of 6.1 fatalities.

Fortunately, such statistics are not reflected in the safety records of UPS. To be as safe as UPS's U.S. Department of Transportation reportable accident frequency denotes, a typical automobile driver would have to drive 1610 km (1,000 mi) a month for 420 years with no accidents. To be as safe as UPS triples, a person would have to drive 1610 km (1,000 mi) a month for 1,000 years. UPS has achieved this enviable safety record with a fleet of trucks of varying ages, many of which do not have the safety features highlighted in the paper. For UPS, safety is in the hands of the driver. Therefore, UPS has made a pragmatic decision to invest in its drivers by hiring high-quality people and requiring extensive training. However, in all its business decisions, UPS must consider the competitive world marketplace in which it operates; therefore, in closing, Hardeman agreed with Ervin's conclusion that a managed, competitive dynamic within truck issues is the appropriate approach. Efficiency and productivity are hurt by barriers erected by competing modes of transportation having little or nothing to do with highway safety or infrastructure. An example is found in the 80,000-lb gross weight limitation in the United States. Its justification is suspect because axle load limits and Bridge Formula B provide all that is necessary to preserve our highway investment and maximize the use of our infrastructure.

Gary S. Moore, *PACCAR, Inc.*

Truck manufacturers have taken several actions to improve truck design, stated Gary Moore, whose company PACCAR, Inc., manufactures both Kenworth and Peterbilt trucks in the United States, Canada, and Mexico. Some of the actions, prodded by EPA regulations to reduce emissions, have led to significant design improvements that also affect other areas. For example, electronic engines used to control emissions also improve fuel economy. Electronics has also allowed manufacturers to provide the driver with more safety information through improved dash displays. Likewise, more aerodynamic designs, incorporated to achieve better fuel efficiency, have improved visibility and thus increased safety.

Moore noted that Ervin's paper failed to cite investigations by manufacturers into the use of alternative fuels. Kenworth, for instance, has two prototype designs that employ alternative

fuels; however, the additional 363.2 kg (800 lb) of fuel tank weight is a disadvantage that must be resolved.

Road conditions—poor road conditions—cause damage to trucks as surely as trucks cause damage to roadways, asserted Moore. The truck naturally responds to the road, and improvements such as air suspension have been introduced to counter poor road conditions. These improvements increase safety by reducing driver fatigue and noise levels. Moore maintained that this interaction of the truck with the roadway requires that truck manufacturers and pavement engineers work together to improve the design of both safety components.

Regarding future trends, Moore believes that antilock brakes will gain acceptance among truck buyers just as they have among the purchasers of passenger automobiles. And changing driver demographics will require better ergonomic designs for cabs and other interior improvements.

In closing, Moore urged that the transportation industry take a systems-level approach to solving safety problems. Truck designs alone cannot solve all of the problems; however, solutions to one problem often can help resolve others. PACCAR has taken an innovative approach by having engineers obtain commercial driver's licenses and travel with the trucks to gain a clear understanding of the trucking environment. Kenworth has also produced a brochure with Chevron entitled "Sharing the Road" that educates automobile drivers about sharing the road with heavy vehicles. Communication is also a key to improved safety, and more opportunities such as this symposium are needed to foster communication among the various parties concerned with motor carrier issues.

Donald Jerry Ehrlich, *WABASH National Corporation*

Opposing Ervin's theory that public and private costs related to truck design are somehow in conflict, Donald Jerry Ehrlich asserted that they are, in fact, closely linked—particularly in light of last year's transportation bill, which exceeded $350 billion. Of that amount, approximately 80 percent was spent on truck transportation. Furthermore, the efficiency of the transportation industry has a direct bearing on the health of the U.S. economy.

More specifically, Ehrlich took issue with the contention that truck purchasers write the vehicle specifications with regard only for the private costs. Trailers, also specified by buyers, have differing specifications for improved productivity. Interior dimensions of a trailer, for instance, can greatly affect the efficiency and productivity of the truck.

Many customers of WABASH, including UPS, continually look for design improvements—such as splash and spray control devices—on a voluntary basis, according to Ehrlich. The underride system that WABASH trucks and several companies are using voluntarily has met the standards since 1986. One problem is that restricting the wheel base of 16.17-m (53-ft) trailers may counter public interests in that the rear suspension becomes overloaded very quickly in this configuration. Thus, the intended load and potential efficiency of the trailer cannot be achieved. The same type of problems may occur with air ride suspensions.

LCVs, although overlooked by Ervin, show promise of increasing productivity in the motor carrier industry while improving safety by reducing the number of vehicles on the road, which also reduces the number of accidents. LCVs, therefore, represent a "win-win" situation for the industry.

The trend toward intermodal transportation will also bring new challenges in truck and trailer design. Ervin predicted the evolution of truck-rail intermodal transportation whereby truck lines now involved primarily in over-the-road services begin to integrate rail service into

part of their operations. The risk will come from having intermodal equipment spend more time on the highways. These chassis are specified for the low end of the scale and are not equipped for long hauls. Container lighting will also become an issue for 16.17-m (53-ft) trailers.

In closing, Ehrlich reiterated that consideration of public and private costs already are being, and must continue to be, taken in concert, not in conflict.

WORKSHOP SUMMARIES

Advanced Concept Vehicles—Designs for More Efficient Trucks

Farrel L. Krall, *Navistar International Transportation Corporation*

The workshop's focus was on meeting the future needs (including societal needs) of a diverse customer base. Three topics were discussed: integrated tractor-trailer design, optimized size and weight vehicle configurations, and evolving intelligent vehicle-highway system (IVHS) technologies for commercial vehicle operations (CVO).

Discussion

Integrated Tractor-Trailer Designs

Significant economizing is possible through integrating tractor-trailer design. Enhanced aerodynamics, advanced brake technology, and advancing engine and powertrain systems for improved fuel efficiency are all driven by the competitive nature of the business and by ongoing technological innovations. Although the integration of tractor-trailer design is largely market-driven, public policy can encourage as well as limit innovations. Thus, a cooperative, proactive process involving both the public and private sectors is needed. Major users (freight movers) will promote innovation, but only if they can do so cost-effectively; thus, major users tend to set the pace of integration.

Optimized Size and Weight Vehicle Configurations

It is important to develop a process for analyzing, synthesizing, and rationalizing various size and weight studies. The Road and Transportation Association of Canada (RTAC) process is a useful model because it has involved the provinces, academia, users, and others. In the United States, bringing federal agencies, congressional aides, representatives of CRASH (Citizens for Responsible and Safe Highways), shippers, and other concerned parties into the process will be crucial. An up-front agreement on objectives and a commitment to implement the research recommendations are also necessary. (Actual structuring of final rules and regulations is bound to be difficult; however, vehicle configurations must be controlled in the final rules to avoid the problem of "loopholes" in vehicle performance standards.) Finally, close oversight of research to avoid cost underestimations and other flaws is imperative.

Containers are an important topic for further research. They are an intermodal and international concern shared by both the trucking and railroad industries. Containers have configuration, weight, and safety implications that should be further explored.

The Coordinating Task Force on Highway/Commercial Vehicle Interface has launched an important education and research coordination process that should be furthered. Following two successful technical orientation sessions, efforts to officially organize this activity under the auspices of TRB and SAE are under way. This organizational effort should be pursued on a priority basis. It was suggested that the National Transportation Safety Board also be a member of this task force.

Evolving IVHS Technologies of CVO

Commercial vehicles are leading the implementation of IVHS as a means of increasing productivity. Demonstration programs are under way to use the advancing technologies of automatic vehicle identification, weigh in motion, and automatic vehicle classification. Workshop participants endorsed an earlier speaker's recommendation that these three IVHS technologies be required on the entire national highway network system. Participants noted the need for motor carriers to become more involved in the many deliberations on IVHS development. Truck manufacturers see a need for system design integration of various evolving IVHS technologies. At present, truck manufacturers are not fully aware of new technologies being developed at the user level, even though a high degree of design integration is necessary.

To remedy this situation, the IVHS-America CVO Committee has recommended the implementation of a proposed CVO needs survey as part of its strategic development plan. This proposed 2-year joint government and industry research study was strongly endorsed by workshop participants. The survey is intended to identify future trucking applications for IVHS technologies and to create a prototype model for assimilating the application of IVHS/CVO technologies.

It is recognized that close coordination of public- and private-sector efforts is needed to bring about the effective implementation of IVHS/CVO technologies. Motor carrier participation in the planning and development process for these technologies is encouraged.

Recommendations

- Integrated tractor-trailer designs would greatly enhance overall combination-unit vehicle aerodynamics, braking efficiency, and powertrain efficiency. A cooperative public/private effort to foster these types of designs was encouraged.
- The RTAC model was offered as a good way for interested parties to come together to optimize the U.S. size and weight configurations for heavy vehicles. The group suggested that the configuration, weight, and safety implications of expanded use of intermodal containers by further explored.
- The organizational efforts begun by the Coordinating Task Force on Highway/Commercial Vehicle Interface should be further pursued on a priority basis. The National Transportation Safety Board should be encouraged to become a member of the task force.
- In terms of developing IVHS/CVO technologies, motor carriers need to become more involved. Truck manufacturers need to become more involved in the integration of the systems into the overall design of their vehicles. To accomplish this, the workshop strongly endorsed the proposed 2-year joint industry and government research study proposed by the IVHS-America CVO Committee as part of its strategic plan development.

Accident Avoidance Technology

Robert M. Clarke, *National Highway Traffic Safety Administration*

Robert Clarke opened the session by encouraging discussion on vehicle design and performance issues, namely, hardware features of trucks that could help prevent truck crashes. He offered three general topics for discussion:

- Advanced technology brake systems (ATBS),
- Dynamic stability and control, and
- IVHS collision avoidance technologies.

The work group suggested additional topics for review, including the adoption of advanced technology training simulators and training schools that incorporate in-vehicle skid pan training, which are both intended to train drivers in recognizing and properly reacting to situations requiring limit-performance crash avoidance steering and braking maneuvers.

Discussion

Electronically Actuated Braking Systems

The early work group discussion on ATBS focused on electronically actuated braking systems (EBS), which is in the early stages of development in the United States and Europe. EBS employs either brake pressure or brake torque feedback from each wheel and has the potential to significantly improve brake application and release timing and brake force balance in combination-unit vehicles. This should result in less maintenance from uneven wear and offer the possibility of on-board brake system functional checking and diagnosis. Many see these systems as a natural outgrowth of the increased use of computer technologies on trucks for engine control and of IVHS efforts.

Foundation Brake Technologies

The work group discussion shifted to foundation brake technologies and the recurring problem of inadequate brake maintenance, especially brake adjustment. The work group agreed that a

high proportion of trucks are routinely placed out of service in roadside inspections for this reason. Results of a recent FHWA study indicated that brake adjustment may be necessary every 4830 to 32 200 km (3,000 to 20,000 mi), depending on the nature and severity of the operation or vocation in which the truck is used. The almost universal use of automatic slack adjusters and the increasing use of long-stroke brake chambers should materially assist in reducing the need for frequent brake adjustments.

Air disc brakes were noted to have superior heat dissipation and fade resistance capabilities, but their acceptance has been marginal. This lack of acceptance may reflect the fact that brake force imbalances often occur when tractors and trailers with mixed S-cam and disc systems are coupled. EBS could help eliminate this problem, thereby facilitating increased use of air disc systems.

As the work group explored brake system inspection and diagnostics, an Australian example was used to show how portable roller dynamometers have greatly aided the brake inspection process for both motor carriers and inspection/enforcement personnel. These devices eliminate the need for brake stroke measurements, which could substantially reduce inspection times and thereby increase the productivity of both inspection personnel and truck operators. In the United States, the Commercial Vehicle Safety Alliance is pilot testing, under FHWA sponsorship, a number of these devices as well as brake heat-sensing, infrared-based systems. The increased use of roller dynamometers, possibly mandatory under the annual vehicle inspection requirements, was an issue that the group thought worthy of further study if the pilot test results are positive.

The work group showed concern that drivers of the many trucks discovered with out-of-adjustment brakes are often unaware of vehicle's condition. Air-braked vehicles, unlike hydraulically braked vehicles, have no kinesthetic pedal feedback cue indicating a deficient braking system. A suggested topic for investigation was the development of appropriate kinesthetic, vestibular, or tactile feedback cues to alert drivers to a vehicle's condition (in this case, brake system adjustment) or to indicate a vehicle's dynamic stability or braking performance limitations.

The work group discussion shifted to antilock braking systems (ABS) and how heavy truck manufacturers in the United States now offer ABS as an option, although market penetration is still low. One opinion was offered that without a federal regulation requiring ABS, market acceptance would remain low. The work group consensus was that ABS should be a mandatory federal requirement.

Size and Weight Regulation

Dynamic stability and control issues and the effect of size and weight regulations were discussed next. The RTAC process was lauded as being a model for government and industry cooperation. Under the RTAC process, research that focused on optimizing vehicle size and dimensions in terms of vehicle productivity, safety, pavement wear, and bridge loading considerations was conducted. Performance standards were developed for individual components (e.g., C-dollies) and for entire vehicle combinations. Greater weight allowances are given vehicles with axle configurations and loadings that minimize pavement and bridge loading effects. Allowances are also made for coupling arrangements that minimize dynamic instability or rollover tendencies. Australia is implementing this quid pro quo approach in its regulations for vehicle size and dimensions. This process was suggested for future U.S. efforts to rationalize and harmonize the requirements for U.S. vehicle size and dimensions with those of the partners in the North American Free Trade Agreement.

Collision Avoidance Technologies

The issue of IVHS collision avoidance technologies was then introduced to the group. Many of these technologies may be applied more beneficially in heavy trucks than in passenger cars.

Near-field object detection devices, or NODS; driver alertness and driving performance monitors; rollover and other hazard-warning devices; and forward-looking object detection and collision avoidance systems are technologies that could be very beneficial in heavy truck applications. The installation of many of these systems on trailers may involve upgrading electrical powering and signaling capabilities. Clearly, more investigation into accommodating these systems is necessary. The work group emphasized that many of these new technologies are being developed by individual suppliers and are marketed directly to the end user or truck operator.

Keeping in mind hardware design compatibilities and human factors, the task of successfully integrating these systems may rest with heavy truck manufacturers, if they choose to install these systems on their vehicles. The integrated systems will need to perform optimally to enhance, rather than compromise, the safety of truck operations. Cooperative efforts in defining appropriate standards may prove desirable in this regard.

A brief discussion followed on the problem of justifying the use of crash avoidance technologies and verifying their crash reduction benefits, using accident statistics. Most accident data bases do not contain sufficient data for highly focused analyses. No accident data collection system now in place or envisioned for the future is likely ever to fill this void. Instead, many highly focused "special issue" studies, of necessity limited in scope and duration, will emerge. When the technologies in question do not yet exist or are not in widespread use, retrospective accident studies will never be possible, increasing reliance on engineering data.

Information submitted for the record but not discussed at the session for lack of time focused on the benefits of providing driver training in emergency crash avoidance driving skills. Training can be accomplished with actual vehicle-on-skid-pan training courses or possibly in advanced technology simulators. Further exploration of the potential benefits of this training was deemed worthwhile.

RECOMMENDATIONS

The following topics were identified as being beneficial areas for cooperative government and industry action:

- Ensure compatibility between electronically and pneumatically braked vehicles in a combination-unit truck.
- Continue efforts to foster more efficient brake inspections by motor carriers and roadside vehicle inspection personnel through the use of advanced technologies such as infrared sensing, roller dynamometers, and brake plate testers.
- Enhance the vestibular, kinesthetic, or tactile feedback cues that truck drivers receive to help them detect vehicle deficiencies or become aware of the limits of a vehicle's dynamic stability performance envelope.
- Adopt the RTAC model of cooperative industry research on vehicle sizes and dimensions as a possible means of furthering objective study of U.S. policies on heavy vehicle size and dimensions.
- Continue cooperative government and industry efforts to foster the development of IVHS collision avoidance technologies while optimizing the human factors that govern them.

Energy and Environmental Issues

Joanne I. Goldhand, *Environmental Protection Agency*

Joanne Goldhand began the session by identifying three major areas in which pollution affects the environment and energy usage: urban (including ozone and particulate smoke), global (carbon dioxide, methane), and waste and storage. After some discussion, noise was added to the list of pollutants. The effects of noise pollution have been deemphasized by the federal government in recent years; indeed, noise pollution is no longer actively enforced by the EPA. An industry representative commented that noise pollution laws remain on the books but that manufacturers essentially police themselves to ensure compliance. There was some feeling among participants that further research must be conducted to determine the extent and effects of noise pollution in urban areas, in industrial terminal locations, and on the road.

Discussion and Recommendations

Goldhand identified three major issue areas for discussion by the group: engine and aftertreatment impacts, operational impacts, and fuel impacts (diesel and alternatives).

Engine and Aftertreatment Impacts

Engine improvements and aftertreatments affect the environment in terms of improved vehicle efficiency, reduced gaseous emissions, and lower noise levels. Goldhand asked whether the United States has gone as far as necessary in affecting gaseous emissions. Group members pointed to the imprecise standards agreed to at the Earth Summit held in Rio de Janeiro, Brazil, and the general uncertainty in this field about goals and capabilities.

In terms of vehicle efficiency, there was the feeling among industry representatives that an efficiency goal of 4.25 km/L (10 mpg) for commercial vehicles may be achievable. An industry representative commented that private industry is not really geared toward the kind of cutting edge research and development required for new technology development. From the industry point of view, the most effective way to encourage changes in vehicle efficiency is a phased-in regulatory process that is not disruptive to business (e.g., incentives to meet "clean engine" requirements that reward businesses for advances in efficiency through the waiving of certain operational standards).

Industry representatives were less than enthusiastic about federal efforts to encourage the use of alternative fuels such as methanol. They pointed out that there are essentially two types of trucking delivery systems: local networks and long-distance hauls. From a user standpoint, diesel will continue to be the fuel of choice for medium and heavy vehicles on longer trips because the United States lacks the infrastructure for other types of fuel delivery. Liquefied natural gas has potential use in city locations but not in long-distance hauls. It was also noted that smaller vehicles are easier to convert to alternative fuels; larger vehicles currently average a 20 percent loss in mileage when they are run on liquefied natural gas, for example.

Consensus found that different analytical, regulatory, and developmental approaches must be taken on issues such as efficiency, fuel additives, and fuel alternatives on the basis of whether the vehicles are being used for long-distance or local hauls. Differing uses require differing levels of efficiency and power. In the area of bus design, for example, weight is a critical issue; buses are among the first motor carriers to be affected by the Clean Air Act. Additional research is needed into lighter-weight materials for vehicle construction.

Operational Impacts

The operational mechanisms used to restrict vehicle movement range from time-of-day restrictions and toll roads to IVHS. The ultimate goals of all these mechanisms include lower emissions, lower costs, and less congestion.

Industry representatives pointed out that many U.S. businesses now assemble parts made in other locations, making transportation a necessary part of production. It was recommended that before planners erect additional barriers to vehicle movement, they should seek ways to make more efficient use of the current system. Suggestions included seeking better integration of traffic flow information obtained by the trucking industry with data gathered by local traffic authorities. It was also suggested that urban planners require architects to include off-street parking and loading facilities in new commercial developments. An Australian representative commented that the commercial side is already regulating itself and finding the most efficient delivery times and routes.

An industry representative complained that the federal government is focusing on restrictions rather than incentives; he pointed out that IVHS is popular among commercial carriers because there are incentives for using it. The group agreed that federal and state regulators should study IVHS and other systems to make sure that incentives are structured to reduce emissions, not just to regulate speed. They also agreed that regulators should consider emissions in any analysis of new technologies.

Fuel Impacts

Participants reiterated their belief that diesel is the fuel of the immediate future. There was consensus that tax structures promoting a certain industry (such as alternative fuels) need to be eliminated once they achieve their goals. These kinds of taxes decrease the revenue available to fund infrastructure projects. Participants questioned whether taxes designed to promote alternative fuel usage are the most effective agents to promote change and whether the changes they bring about are desirable.

There was a general feeling that the federal government should continue to support research and demonstration programs involving alternative fuels and improved engine capabilities. One participant from the academic community suggested that the federal government not prejudge which fuels work; instead, it should tax emissions and let innovation determine how emissions standards are met, thus allowing user input into the process.

Driver Workplace

Gary W. Rossow, *Freightliner Corporation*

Gary Rossow opened the session by commenting that safety, efficiency, and comfort are the watchwords of the driver's workplace, suggesting three areas for addressing them:

- Occupant protection that encompasses safety aspects affecting the driver (e.g., crashworthiness),
- Vehicle-driver interface issues (e.g., controls, displays, and information overload), and
- Driver fatigue and its relationship to comfort, ride quality, and so forth.

Rossow briefly reviewed the status of the SAE research project on crashworthiness and occupant protection. It was suggested that SAE and many government and industry sponsors were addressing this topic adequately.

Discussion

On the topic of vehicle-driver interface, high-technology instrumentation and "how much stuff is enough" (or too much) was the centerpiece of much of the discussion. Participants questioned what defines driving advances in instrumentation and controls: the technical ability to create more bells and whistles or the driver's need for them? The answer: both. A carrier representative said that instrumentation is becoming so sophisticated that tomorrow's truck drivers will have to be highly educated. Concern was voiced about the lack of guidelines for manufacturers on the type, quantity, and physical positioning of instruments and displays.

An FHWA representative reported on current research in related areas, including impacts of longer combination vehicles on driver fatigue and other factors and a review of IVHS technologies. Overall, there was a lack of understanding about whether the apparently fragmented government and industry research activities on these topics were addressing all the concerns.

It was noted that the Canadian Trucking Research Institute is developing a simulator for driver training. It would be useful if it or other simulators could incorporate vehicle dynamics to test drivers' reactions to hazardous situations or to be used as an evaluation tool for high-tech instrumentation.

Driver fatigue—or alertness—was the third topic. The progress of the fatigue study sponsored by FHWA and the American Trucking Associations was discussed. It was also noted that a major study on driver sleep disorders was initiated last year but that no results have been reported. Concerns about how and when driver studies are conducted arose. For example, the use of relatively short-haul, less-than-truckload operations over fixed routes may not represent the characteristic driver work patterns of coast-to-coast truckload or owner-operator service. A carrier pointed out that shippers' demands and schedules sometimes have a strong impact on fatigue; drivers may drive for 15 hr if it means staying in business. Although hours-of-service regulatory issues appear to be the subject of much of the research, there is a growing recognition of other factors, such as the 24-hr biological aspects and fundamental desire of drivers to return home. It was asked—but not answered—what relationship exists between fatigue and cab comfort, ride quality, noise level, and amenities.

A government representative noted the need to determine appropriate countermeasures for driver-related workplace issues. Some suggested that the underlying accident data needed to define the problems were still not available, citing the recent recommendations from TRB's *Special Report 228: Data Requirements for Monitoring Truck Safety*. It was noted that some of the TRB recommendations are being implemented.

Recommendations

Several recommendations were made:

- Resurrect Special Report 228 and use it as a blueprint to build the factual data base to respond to these and other issues.
- Investigate the Bureau of Transportation Statistics (established through the Intermodal Surface Transportation Efficiency Act of 1991) as a mechanism to put the aforementioned suggestion into an intermodal discussion of issues and recommendations.
- Develop a carrier-initiated research agenda on driver-vehicle interaction issues (e.g., instrumentation overload) before Congress or the regulators establish policies on the basis of what "gadgets" are available; this research must be solid and unassailable.
- Review the IVHS/CVO study on high-tech instrumentation to compare instruments' usefulness and cost-effectiveness in relation to drivers' needs and abilities to use information effectively.
- Get the trucking and shipping communities to work cooperatively to examine the effect of logistics management demands on drivers and the relationship of these demands to fatigue and other concerns.

SAFE AND EFFICIENT MOTOR CARRIER OPERATIONS

Keynote Address

Donald J. Schneider, *Schneider National, Inc.*

As president of a large national trucking operation, Donald Schneider was well positioned to address the issues presented by this forum. His firm is an asset-based logistics company running extensively between and within Canada, the United States, and Mexico. His is an intermodal operation whose business is to "move customers' freight in compliance with their product supply chain," qualities descriptive of several themes and operating motifs discussed at this symposium. A summary of his discussion follows.

Over the past 10 years, business has driven inventory out in order to get an adequate return on investment. As inventories fall, a higher level of service is demanded from carriers, who are positioned to respond to these new demands only because of their own improved efficiencies. Logistics costs have decreased while vehicle size has increased, both factors contributing to the overall increased productivity of motor carriers.

Several points flow from the economic realities of companies' lowering their inventories and demanding higher performance from carriers. These points help form the argument that efficiency and safety are not mutually exclusive but natural allies. Because marketplace forces demand better performance by carriers, carriers in turn are investing in larger vehicles, better drivers, more maintenance, and technologies that will make them more efficient. These investments elicit better management from carriers and result in higher productivity as well as increased safety.

The following points elaborate on this thesis:

- Safety and efficiency are not in conflict. A well-managed, productive operation, which is being demanded by the marketplace today, will be a safer operation.
- Technology has improved both efficiency and safety. Many trucks are outfitted with computers that give the driver "safety macros," such as average speed for a set period. Furthermore, technological improvements have enabled companies to schedule deliveries and drivers more efficiently to give drivers the time off that they need.
- Regulation can be detrimental to safe operations. When regulations are design-driven, they stifle creative innovation that comes from the marketplace—particularly because a given regulation can never address all the unique factors governing different situations. They tend to become outdated quickly and can actually increase hazards.
- Truck and rail technologies are unique. The marketplace will demand the appropriate mode for the appropriate load. Each mode will ultimately allow each technology to reach its

full potential for the benefit of this country, of customers, and of the motor carrier industry, which will be able to take advantage of new opportunities.

- Longer combination vehicles are safe and efficient technologies when managed properly. They are a complement to, not a competitor with, motor carrier and rail industries.
- Truck weight increased by more axles improves safety and efficiency.
- Harmonization of size and weight in North America improves efficiency and safety. The difference in standards is having a negative impact on safety and efficiency. The more confusion that surrounds safety rules, the harder it is for drivers to comply with them.
- The marketplace is the best source for direction on safety and efficiency. Too much rigidity frustrates creativity and impedes the provision of service to customers in the most efficient—and therefore safe—manner.

In conclusion, the improved efficiency of vehicles, productivity, and logistics ultimately leads to increased safety factors, and these events are marketplace-driven. Schneider fielded questions from the audience after his talk. One point he made is that the United States and Canada will both benefit from the North American Free Trade Agreement because it promotes business.

State Administration of Motor Carrier Requirements: Opportunities for Creative Partnerships

John J. Zogby, *InfoGroup, Inc.*

The purpose of this paper is to explore the effects of state administration of motor carrier requirements on the safe and efficient operation of heavy trucks. Because heavy trucks account for a significant number of highway deaths and injuries, the safety of such vehicles has been the subject of much research, legislation, and regulatory activity. The effects of recent research, legislation, and regulations on heavy truck safety will be examined, and some of the recommendations from these endeavors will be highlighted. The basic hypothesis is that the most effective solutions to the emerging safety problems with heavy trucks are found in policy initiatives rather than technology.

An underlying thesis is that effective administration of motor carrier safety programs, both public and private, requires an understanding of government regulatory policy and the motor carriage business. This thesis takes for granted that business and public administrators are well versed in the methodologies of their discipline. They should know at least some of the basics of such methods as management science, systems theory, budgeting, public policy analysis, operations research, and statistical analysis.

But the public administrator must also know some basics of the motor carriage business that they regulate, and the industry administrator should know the reasons for, and method of, motor carrier regulation. Administrators who do not learn them, or who ignore them, are vulnerable to snow jobs and technical jargon. And administrators can ill afford to have their management prerogatives pass down to technical specialists because of their own ignorance.

Introduction

Before the history of motor carrier legislation and regulation is presented, a review of some major items in the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) (*1*) would be in order, since the author believes that this legislation offers the opportunities for the creative partnerships suggested in this paper. Section 2 of the act, the Declaration of Policy, lists the policy statements that provide the philosophic underpinnings of this major transportation legislation. The first two statements capture the essence of the overall mission of the act:

> It is the policy of the United States to develop a National Intermodal Transportation System that is economically efficient and environmentally sound, provides the foundation for the Nation to

> compete in the global economy, and will move people and goods in an energy efficient manner. . . .
>
> The National Intermodal Transportation System shall consist of all forms of transportation in a unified, interconnected manner, including the transportation systems of the future, to reduce energy consumption and air pollution while promoting economic development and supporting the Nation's preeminent position in international commerce. (*1*)

ISTEA has set the stage for a new era in transportation management. Environmental considerations alone have introduced a new set of managers in the policy and implementation phases. Additionally, the requirement for long-range development plans for states and metropolitan areas has changed the planning and decision structure, also introducing new players in the decision-making process. In this regard, ISTEA

- Establishes a National Highway System to focus federal resources on roads that are most important to interstate travel, that connect with other modes of transportation, and that are essential for intermodal commerce;
- Gives state and local governments more flexibility in determining their transportation needs and resolving their transportation problems;
- Mandates the use of enhanced planning and management systems to guide the state and local government in making choices; and
- Encourages, through funding, new technology such as intelligent vehicle-highway systems (IVHS).

In regard to motor carriers, ISTEA

- Reauthorizes and expands the Motor Carrier Safety Assistance Program (MCSAP),
- Recognizes uniform commercial vehicle registration and fuel tax reporting agreements,
- Requires driver training studies and standards, and
- Repeals the "bingo stamp" program.

Motor carriers will play a vital role in fulfilling the objective of this act. The contribution of the industry, in meeting the mission of ISTEA, will depend on the management of motor carriage issues and services by the industry and by federal and state government. This management must be coordinated and must understand the interconnection of economic, transportation system development, and motor carrier safety regulatory goals.

The trucking industry is composed of approximately 253,000 American firms and accounts for 78 percent of all freight transportation revenues in this country. It employs 7.6 million people and generates annual revenues in excess of $257 billion. The public and the American economy depend heavily on truck transportation to provide the goods, services, and materials that move America (*2*).

Despite this, the number of highway crashes involving heavy trucks, as well as their size and increasing number in traffic, has prompted concern among public and industry officials alike. Even while acknowledging the vital services that the trucks provide, many members of the driving public perceive large trucks as menaces on the road. This perception is fueled by media reports such as a *Readers Digest* report titled "Killer Trucks" and *USA Today*'s headline announcing "1 in 4 tractor-trailers rigged for disaster."

Truck Crash Experience

However, the reality is that from 1979 through 1989, the number of fatal crashes involving trucks remained fairly constant, deviating little from an average of 3,823 fatal crashes a year (see Figure 1). The fatal crash rate of combination vehicles decreased significantly, from 6.4 fatal crashes per 100 million mi of travel in 1979 to 3.8 in 1989. However, this rate is twice the 1.9 rate for passenger vehicles (see Figure 2) (*3*).

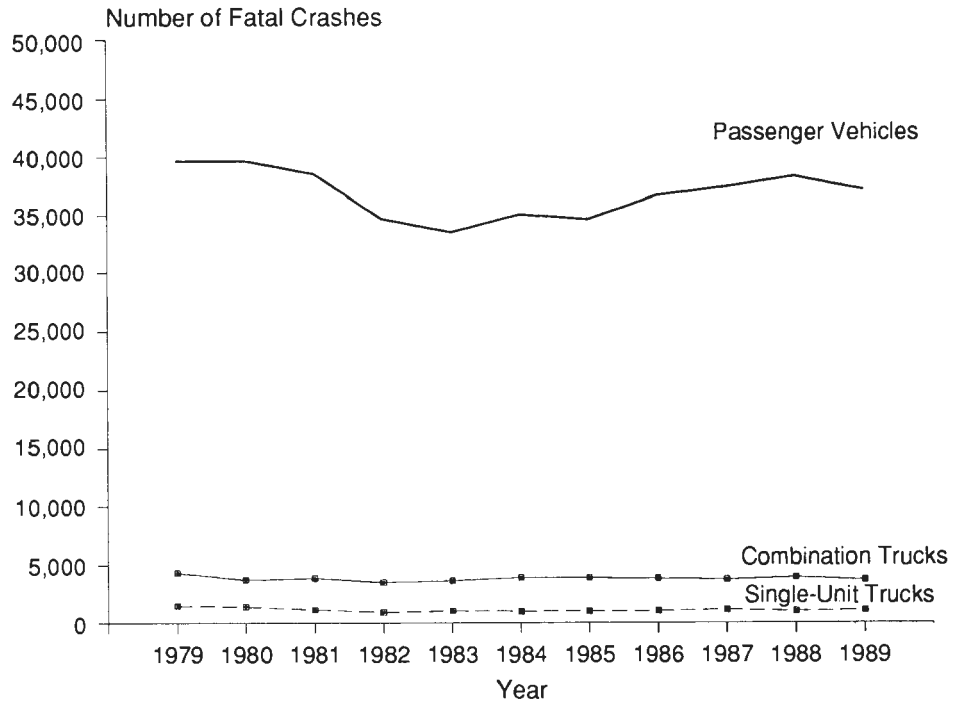

FIGURE 1 Fatal crashes by vehicle type and year, 1979 through 1989 (*3*).

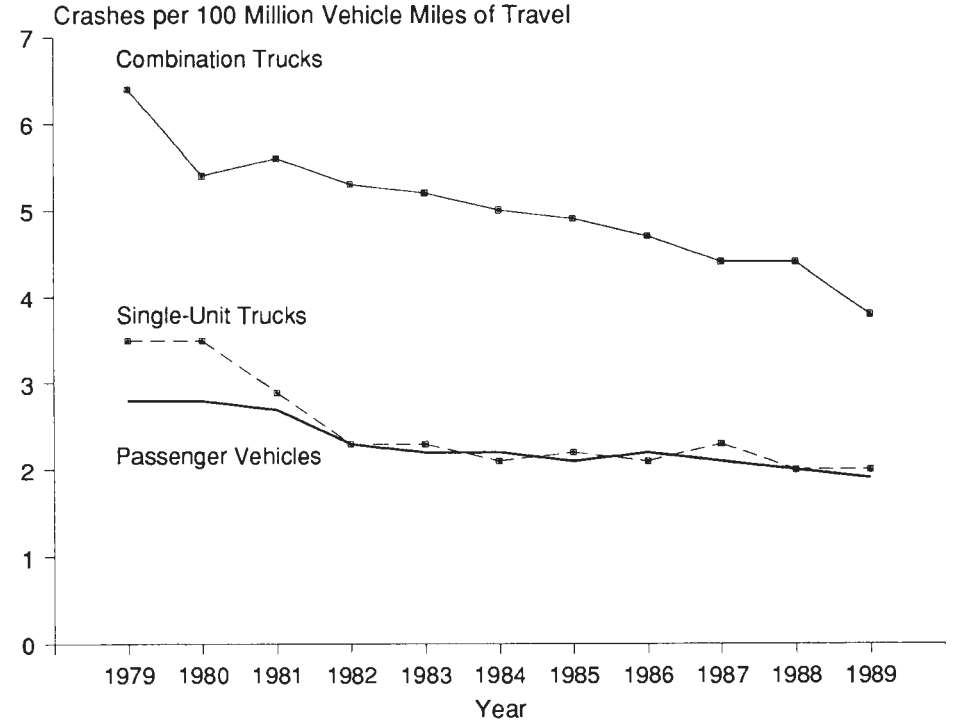

FIGURE 2 Fatal crash rates by vehicle type and year, 1979 through 1989 (*3*).

Medium and heavy trucks—that is, trucks with gross vehicle weight ratings over 10,000 lb—drove almost 150 billion mi in 1989, 7 percent of the 2.1 trillion mi driven by all vehicles. Trucks accounted for only 3 percent of the nation's vehicle fleet in 1989. On the basis of registered vehicles, combination trucks drove an average of 60,000 mi, straight trucks averaged 13,000 mi, and passenger vehicles averaged 11,000 mi. Of the 12 million vehicles involved in crashes of all severity, trucks made up 3 percent, or 349,000. For fatal crashes, however, 4,985 (8 percent) of the 60,870 vehicles involved were trucks. A total of 5,491 people lost their lives in truck crashes, but only 16 percent were truck occupants. Of the 124,000 people injured in truck crashes, only 26 percent were truck occupants (*3*).

The Congressional Office of Technology Assessment (OTA), in its study *Gearing Up for Safety: Motor Carrier Safety in a Competitive Environment* (*4*), made the same observation: that while annual fatalities in heavy truck crashes have remained constant over the past 10 years, four out of every five people killed in crashes involving tractor-trailers are occupants of the other vehicles.

The analysis of federal crash data in the study pointed to three significant findings. The first is that speed is a dominant factor in serious truck crashes. This finding implies a need to focus on speed limits as well as human factors and technologies related to controlling speed. Industry practice varies widely in this area. The study found that some large companies install speed governors set at about 55 mph on their fleets (at the time, the national speed limit), both to conserve fuel and to control the speed of the vehicle. The study also found that many truck drivers owned and used radar detectors and radar jamming devices for the sole purpose of avoiding detection when speeding. As a corollary, the study also found that a large number of truck drivers involved in crashes had prior records of speeding and other moving violations, as well as previous crashes. This finding is corroborated by information from NHTSA's *Summary of Medium and Heavy Truck Crashes in 1989* (*3*) (Table 1).

The second finding is the low level of driver training. The research showed that most drivers involved in crashes have never had any driver training. This finding indicates a need for specific attention to training programs with consideration for developing national guidelines and certification requirements for truck driver training programs. The study investigators also believe a key issue is on-the-road experience of prospective drivers. They recommend that the U.S. Department of Transportation (DOT) encourage carriers to develop apprentice programs that follow national guidelines.

The third finding in the truck crash data is the relationship of age of the vehicles involved in crashes. The age of the fleet has increased, and the expenditure on maintenance as a proportion of company income has remained flat. The study also found that 40 percent of heavy trucks involved in crashes are not subject to federal safety regulation.

TABLE 1 Drivers Involved in Fatal Crashes by Prior Convictions and Involvements and Vehicle Type, 1989

	Truck Drivers (n = 4,904)		Car Drivers (n = 50,785)	
Prior Conviction and Involvement	Number	Percentage	Number	Percentage
Recorded accident	1,109	23	8,875	17
Recorded suspension	490	10	6,072	12
DWI conviction	92	2	2,279	4
Speeding conviction	1,711	35	12,235	25
Other conviction for harmful moving violation	1,120	23	8,786	17

NOTE: Drivers can appear in more than one conviction and involvement category.
SOURCE: NHTSA

Federal and State Motor Carrier Regulation

Motor carriage issues have been a concern of federal and state government for decades. State governments have been regulating motor vehicle dimensions since the early 1900s. Width restrictions were the most common form of state size regulation until the 1930s. In the 1930s states began regulating height and length dimensions. The Federal Aid Highway Act of 1956, which authorized financing and funding of the Interstate highway system, also introduced the first federal limits on truck size and weight (*5*). However, the federal government has been involved in motor carrier safety issues since 1935, when Congress enacted the Motor Carrier Act. The major purpose of the act was to preserve and foster efficient and economical highway movements in interstate commerce and to ensure the safety of operations of commercial vehicles. The act authorized the Interstate Commerce Commission (ICC) to issue regulations for certain motor carriers with respect to maximum hours of service, qualification of employees, and safety of operation and equipment. In 1936, under the authority of the Motor Carrier Act of 1935, the ICC promulgated the original Motor Carrier Safety Regulations (*6*).

The 1980s were particularly difficult for the trucking industry throughout the nation. The slowdown of the economy in the late 1970s and early 1980s reduced the demand for the movement of goods by truck; economic deregulation, required by the Motor Carrier Act of 1980, created a very different marketplace for motor carriers. Barriers to entry into the business and in selected markets were eliminated as a practical matter. Pricing was also deregulated. More than 25,000 carriers have entered the industry since deregulation, the vast majority of which are small truckload operators. The entry of so many new and small truckload operators created much excess capacity and made truckload rates highly competitive. Many trucking companies could not adapt to these changes and were forced out of business.

Many opponents of economic deregulation predicted that its effects would create a deteriorating safety climate. This projection was based on predicted financial pressures that would result in deferred maintenance of equipment and aging of equipment beyond accepted life-cycle schedules for repurchase. A motor carrier strapped for cash in an intensely competitive deregulated environment will consider alternatives to replacing equipment. An obvious alternative is to keep and operate equipment longer, in which case the equipment would need more maintenance. Most maintenance can be deferred except for those elements that literally prevent the vehicle from being driven. Maintenance, especially preventive maintenance, can do much to keep older equipment safely in use. The financial pressures brought on by deregulation, to a large degree, affect those carriers that can least afford the costs of new equipment or the associated maintenance costs of aging equipment. During this period government and industry were experiencing financial difficulties, and downsizing and cutbacks in programs were common. Government and industry officials alike claimed that trucking safety programs experienced the most severe cutbacks, especially in certain segments of the industry. At a time when the trucking industry was trying to adapt to the effects of a slow economy and deregulation, state governments, especially in the Midwest and Northeast, were faced with a deteriorating highway infrastructure that would require extensive infusions of dollars to reverse the deteriorating trend. The states in turn sought and enacted tax increases on highway users, in some cases placing a heavier burden on the trucking industry. These actions added to the adverse financial environment of certain segments of the industry.

The framers of the Motor Carrier Act of 1980 had foreseen some of these consequences and in Section 19 of the act required the Secretary of DOT and the Chairman of the ICC to "develop legislative or other recommendations to provide a more efficient and equitable system of state regulations for interstate motor carriers." In their report to Congress, *Section 19—Uniform State Regulations* (*6*), both federal agencies recommended more uniform and less cumbersome regulatory requirements of the motor carrier industry. In the area of safety the report encouraged states to adopt the Federal Motor Carrier Safety Regulations and apply them to all motor carriers by all levels of government. The report also offered recommendations for hazardous materials regulations and oversize and overweight permitting practices. The Motor Carrier Act

of 1980 and the Section 19 report were more concerned with economic relief and efficiencies, but they laid the groundwork for the safety initiatives in future legislative actions.

Although many studies on the impacts of deregulation have been undertaken, questions have lingered about the adequacy of existing federal safety policies and programs. In direct response to this growing concern, starting with the Motor Carrier Act of 1980 to the most recent Motor Carrier Act of 1991, Congress enacted 11 legislative initiatives with significant impact on government and industry in the area of motor carrier safety. These acts dramatically raised the degree and level of governmental involvement in commercial vehicle safety (see Table 2). They created a steadily growing demand for more and tighter inspection and enforcement of safety regulations for motor carrier equipment. Three are of special significance to the states.

TABLE 2 Major Laws Affecting Motor Carrier Safety

Law	Provisions
Motor Carrier Act of 1980	Directed DOT to establish levels of insurance for ICC-regulated truckers and private and intrastate carriers of hazardous materials.
Surface Transportation Assistance Act of 1982	Established MCSAP, directed DOT to designate routes for larger trucks, mandated that states allow 80,000-lb vehicles on the Interstate system, and increased the use tax on certain vehicles and the federal gasoline and diesel tax.
Bus Regulatory Reform Act of 1982	Directed DOT to establish minimum insurance levels for interstate for-hire bus operators.
Motor Carrier Safety Act of 1984	Directed DOT to revise the Federal Motor Carrier Safety Regulations, preempt state safety requirements affecting interstate commerce that are not compatible with federal regulations, and establish procedures for determining the safety fitness of carriers.
Commercial Motor Vehicle Safety Act of 1986	Directed DOT to establish federal standards for states to test and license truck and bus drivers, establish uniform penalties for drivers convicted of serious violations in a truck or bus, and establish an information system containing data on drivers.
Truck and Bus Safety and Regulatory Reform Act of 1988	Directed DOT to eliminate certain commercial zone exemptions from the federal safety regulations and conduct rule making on driver hours of service, on-board recording devices, emergency flares, brake maintenance and inspection, and biometric identification systems for CDL records.
Motor Carrier Safety Act of 1990	Directed DOT to publicize the names of motor carriers with unsafe procedures, prohibit carriers with unsatisfactory ratings from transporting hazardous materials or passengers, establish procedures to require a highway safety specialist to initiate an enforcement action during a carrier review or whenever a serious safety violation can be proven, and establish a system to ensure that states are imposing penalties on carriers failing to return reinspection certifications.
Sanitary Food Transportation Act of 1990	Required DOT in consultation with the U.S. Department of Health and Human Services, the Environmental Protection Agency, and the U.S. Department of Agriculture to issue regulations regarding the safe transportation of food, food additives, drugs, devices, and cosmetics in motor and rail vehicles, including tank trucks, rail tank cars, or cargo tanks that are also used to transport either refuse or other nonfood products that would make food products unsafe for humans.
Hazardous Materials Transportation Uniform Safety Act of 1990	Required DOT to additional regulations for the safe transportation of hazardous materials in interstate, intrastate, and foreign commerce. These regulations must address registration, highway routing, and safety permits.
Omnibus Transportation Employee Testing Act of 1991	Required DOT to establish regulations requiring intrastate and interstate drivers of private, for-hire, and government-owned heavy trucks and buses to be tested for alcohol and controlled substances.
Motor Carrier Act of 1991	Reauthorized and expanded the MCSAP, recognized uniform commercial vehicle registration and fuel tax reporting agreements, limited the operation of longer combination vehicles, required driver training studies and standards, amended the CDL requirements, and repealed the bingo stamp program.

Surface Transportation Assistance Act of 1982

The Surface Transportation Assistance Act (STAA) of 1982 established the MCSAP, which provided federal funds for state adoption and enforcement of motor carrier safety regulations, greatly expanding the existing federal inspection force. Before MCSAP, FHWA safety specialists conducted 36,000 motor carrier vehicle and driver inspections a year. During fiscal year 1991, state inspection officials conducted approximately 1.6 million safety inspections nationally (*7*).

The STAA also raised taxes and fees on carriers and allowed increased access for larger and heavier trucks. The increases in fees and taxes were required to provide funding to rehabilitate the aging infrastructure of Interstate and major arterial highways and bridges in the nation, but the costs to the industry further exacerbated the financial pressures of marginally profitable companies during a recessionary period, thereby encouraging more deferred maintenance and delayed replacement of aging equipment.

The concern for the safety performance of large trucks was heightened by the expanded use of double combination tractor-trailers on Interstates and designated state and local roads following the passage of the STAA of 1982. Since the completion of large segments of the Interstate system in the 1960s, major productivity gains were realized by the industry and were followed by increased truck traffic and gradual increases in average size and weight of trucks. Over time, substantial changes had taken place in the size, mix, and volume of trucks on such highways, prompting FHWA to sponsor research into large truck safety during the 1970s. Findings from these research projects were examined closely as part of the deliberation of more liberal truck size limits incorporated in the STAA of 1982.

Commercial Motor Vehicle Safety Act of 1986

The passage of the Commercial Motor Vehicle Safety Act (CMVSA) of 1986 placed a national emphasis on establishing a uniform national program to identify, qualify, and control commercial drivers. With financial help from FHWA, the American Association of Motor Vehicle Administrators, with the member jurisdictions, developed a valid and reliable set of knowledge and skill tests designed to examine and qualify commercial drivers. The Commercial Driver License Information System (CDLIS), a national telecommunications and data exchange system to track truck and bus drivers with respect to license administration, was also developed. To date more than 6 million drivers have been qualified to the CMVSA standard and possess a nationally recognized commercial driver license (CDL).

Motor Carrier Act of 1991

Title IV of ISTEA, the Motor Carrier Act of 1991, reauthorizes and expands MCSAP, recognizes uniform commercial vehicle registration and fuel tax reporting agreements, limits the operation of double and triple trailer combinations with a gross weight of more than 80,000 lb, requires driver training studies and standards, and repeals the state public utility requirements for documents (cards kept in the truck cab) indicating payment of entry fees. The cab cards are commonly referred to as the "bingo stamp" program.

The expansion of MCSAP under the act allows states to incorporate truck weight enforcement and controlled substance interdiction activities and enforce state traffic laws in conjunction with MCSAP roadside inspections. The uniformity provision calls for the states to join the International Registration Plan and the International Fuel Tax Agreement by 1996. It also directs FHWA to conduct a feasibility study for a national Commercial Vehicle Information System (CVIS), which will serve as a clearinghouse and depository of information pertaining to state registration and licensing of commercial motor vehicles and the safety fitness of the registrants of such vehicles. FHWA is directed to initiate rule making to establish minimum

training requirements for longer combination vehicles and propose rule making for entry-level training for all other operators os heavy trucks. Finally, it includes license disqualifications under the CMVSA to include violations of out-of-service orders by drivers.

Federal, State, and Industry Motor Carrier Programs

Many government agencies at the federal and state levels are involved in motor carrier programs, for reasons as varied as the types of agencies. For the most part, Congress and state legislatures placed responsibility for these programs in the executive agency with the expertise and mandated responsibility at the time of the congressional or legislative action.

Federal Programs

The agencies involved at the federal level for the programs of concern are as follows:

- FHWA
  - –Truck access issues;
  - –Highway design and research;
  - –Establishment and enforcement of motor carrier regulations, including driver and equipment maintenance requirements;
  - –hazardous material regulation enforcement for motor carriers, shippers by highway, and cargo tank manufacturers;
  - –Truck size and weight; and
  - –Longer combination vehicle policy.
- NHTSA
  - –Vehicle design standards,
  - –Hazardous moving violations, and
  - –Accident reporting and investigation.

And the Research and Special Programs Administration establishes regulations for transporting hazardous materials.

These agencies, all within DOT, are involved in varying levels of cooperation in administering their programs. In addition, the ICC is still involved in some regulatory activity, such as insurance requirements, but since 1967 the safety programs have been transferred to FHWA, in particular the Office of Motor Carriers.

FHWA has developed three national programs to ensure compliance with federal safety requirements. The Educational and Technical Assistance Program is designed to encourage carrier compliance with federal safety requirements by upgrading their knowledge and understanding of these requirements and to establish a safety rating for the carrier. Second, the Selective Compliance and Enforcement Program is targeted at carriers that receive an unsatisfactory or conditional safety rating as part of FHWA's safety fitness review. Education and enforcement actions may be applied on the basis of finding results. FHWA also does a compliance review on carriers about which they receive complaints. Third, the Commercial Accident Prevention and Evaluation Program assists motor carriers in identifying causal factors of crashes involving their vehicles for possible countermeasure initiatives (7).

To support these programs FHWA, with the cooperation of the states and the industry, developed an information system, the Motor Carrier Management Information System (MCMIS). Since the states and motor carriers provide much of the data for this system, FHWA maintains records available for state and motor carrier use in developing or evaluating their respective safety programs. Thus far the FHWA effort is resulting in a higher percentage of satisfactory safety ratings of carriers inspected.

State Programs

The experience of fragmentation of motor carrier programs at the state level is even more diverse than that at the federal level. The departments of transportation, police, motor vehicles, driver licensing, revenue, environmental resources, and the public utilities or service commissions all play a role. In addition, state legislatures and policy officials in the governors' offices are actively involved.

The major state motor carrier safety programs are cooperative programs with FHWA. These are MCSAP and the CDL program instigated by congressional action and administered by FHWA. As mentioned earlier, MCSAP dramatically increased the number of commercial vehicle safety inspections across the nation. Of the 1.6 million inspections performed by participating states in 1991, 146,000 included hazardous materials cargos and 27,000 were bus inspections. As a result of these inspections 497,000 vehicles (31 percent) and 126,000 drivers (8 percent) were placed out of service for critical violations. In addition, 9,500 safety and compliance reviews were conducted (*8*).

Corollary to the MCSAP, FHWA has trained more than 6,600 federal, state, and local law enforcement personnel in the detection of illegal use of drugs, or their transportation, during roadside inspections. The program is still in its infancy, but as of February 1993, more than 140 major drug seizures had occurred, resulting in the confiscation of drugs valued at more than $310 million. ISTEA provides funds for the expansion of this program with MCSAP.

The 1986 CMVSA is the second major cooperative effort between FHWA and the states. The primary thrust of this act directed DOT to establish federal minimum standards for licensing, testing, qualifying, classifying, and monitoring commercial drivers. These standards would prohibit commercial drivers from possessing more than one commercial license, require that commercial drivers pass meaningful knowledge and driving tests (with special qualifications for hazardous materials drivers), establish minimum disqualification provisions, and provide that a driver found to have blood alcohol content of 0.04 percent or more would receive a 1-year license suspension for the first offense and permanent license revocation for subsequent offenses. The effective date for all states to be in compliance with the CDL provisions of the act was April 1, 1992. It is too early to assess the success of the safety impacts of the act, since the mandated sanctions implementation is scheduled for October 1, 1993. However, all states are in compliance with the license requirements, and early indications are very positive.

These two major programs, MCSAP and CDL, enhanced existing inspection and driver licensing programs in the states and more importantly forced uniformity among the states in standards and practice. However, in addition to these, states have been administering commercial vehicle safety programs since the early 1900s. Among these are periodic safety inspection programs, weight and size enforcement, safety education programs, safe transportation of hazardous materials, and highway improvements relating to commercial traffic.

Industry Programs

The organizationally fragmented governmental framework appears simple when compared with the diversity of the motor carrier industries. Generally, the industry is divided into four major groupings:

- For-hire trucking, which includes common and contract carriers, inter- and intrastate, and local and exempt carriers;
- Private trucking, such as manufacturers, food distributors, public utilities, construction, and mining;
- Intercity buses; and
- Others, such as government trucks, school buses, and urban buses.

This complexity is exacerbated by the diversity within each grouping. A carrier can own anywhere from one truck to many thousands.

Some large motor carriers have in-house training, driver and vehicle inspection, and maintenance programs to increase operating safety. Some have established a full-time safety position with duties to conduct on-the-road safety surveillance. An exemplary program over the years has been one developed by United Parcel Service (UPS). UPS made a corporate commitment to safety to achieve a highway safety record considerably above the industry average. Its comprehensive safety program includes driver qualifications, rigorous training, regular vehicle schedules, and stringent vehicle maintenance. Honor awards are given to employees for safe driving. Drivers are assigned to the same vehicle over long periods of time, thus improving their familiarity with the vehicle's driving performance. UPS also follows special maintenance practices and strict preventive maintenance inspection standards, which improve the reliability of their trucks and also extend vehicle service life. It is not uncommon for UPS drivers to achieve 25 or more years of crash-free driving (*9*).

MCSAP has become a highly visible safety initiative that has been positively received by a large segment of the industry. The American Trucking Associations, a national trade association of the larger carriers, has supported the MCSAP legislation. It has actively sought to improve compliance with regulations; shape the skill, knowledge, and attitudes of drivers; and ensure that vehicles are built and maintained for maximum safety. The industry was also actively involved in the formulation, draft, and support of the CMVSA of 1986. They participated with FHWA and the states in the development of the testing standards and the driver training programs relating to the CDL tests.

However, most carriers are operated by one or two people who own 1 to 10 trucks. These carriers do not have such safety programs as part of their routine operations. Certain segments of the industry have been strong and early advocates for congressional and DOT safety initiatives, since they participated in their formulation, but many carriers opposed these measures and remain in opposition to this day.

Opportunities

The motor carrier safety environment has been enhanced over the past decade through the combined efforts of Congress, federal and state government agencies, and the motor carrier industry. Many of the initiatives implemented in this time frame are proving successful or are showing promise of success in reducing the frequency and severity of commercial vehicle crashes and incidents. Additional safety enhancement opportunities are identified in the OTA study (*4*) and a more recent effort by a TRB committee (*10*). Listed are opportunities identified in the TRB report for commercial vehicle safety:

- Initiate a comprehensive government and industry program to accelerate the introduction of safety technology into the new truck fleet system. Safety enhancements such as improved truck stopping distances, improved stability, increased conspicuity, reduced underride potential, improved crashworthiness, and occupant protection in cab area should be considered.
- Assess critically the relative effectiveness of the various enforcement activities for motor carriers. The assessment should address the relative roles of federal, state, and local governments in conjunction with the industry. This information should be used to develop guidelines to ensure the most effective use of human and financial resources in improving motor carrier safety.
- Develop reliable and cost-effective methods to detect, and remove from operation, drivers who are impaired by drug or alcohol use or excess fatigue.
- Review and upgrade design practices for highway facilities to ensure sufficient consideration is given to commercial vehicles, such as the use of vehicles with longer wheelbase designs for turning, more roadside rest areas, installation of mandatory truck stops at the crest of steep grades with historically high crash frequency, reduced speed limits and arrestor beds on these types of grades, and signing at locations that present operational difficulty for large commercial vehicles.

- Develop a means to better identify chronic motor carrier violators and bring them to the attention of both public and private sector groups for corrective action. The Safetynet and CDL information systems provide an excellent tool for this effort.
- Develop effective economic disincentives to eliminate advantages currently associated with "illegal" operation. Such disincentives could include fines, penalties, and other sanctions that outweigh any economic gain of the illegal operation.
- Develop innovative programs, in conjunction with the preceding items, to identify and improve commercial drivers who have specific problems with driving performance and specify target improvement activities. Although the new CDL addresses commercial driver qualifications, it does not address any improvement efforts targeted at commercial drivers.
- Evaluate the CDL program. It is the largest national effort to date aimed at controlling a major group of drivers. The federal and state governments and the industry have committed large resources to this effort. A careful evaluation is warranted to ascertain what benefits have been obtained. In addition, if proven beneficial this program should be the model for all categories of driver licensing programs.
- Assist the trucking industry to establish and implement standard training through driver school certification using FHWA's Proposed Minimum Standards for Training Tractor-Trailer Drivers.
- Expand drug testing efforts already under way to ultimately implement a mandatory random drug testing program.
- Develop a multiyear plan for hazardous materials transportation that cuts across the responsibilities of all federal and state agencies involved in their movement, packaging, placarding, inspection, and enforcement.
- Develop and implement a coordinated national strategic management system for motor carriage, which includes goods movement and safety.

Opportunities in research are well-defined in TRB's *Special Report 229* (*11*). The report suggests five areas of research concerning large truck safety. The study cites the growth in the number and size of trucks expected in the traffic stream as the industry continues to take advantage of the increased size allowances of the STAA of 1982 and projected growth rates of combination truck traffic. [The Highway Performance Monitoring System data project an annual growth rate of 3.3 percent over the next decade for combination vehicles, well above the 2.3 percent average annual growth projected for traffic of all types.]

The study suggests a more concentrated effort in the following five areas:

1. *Performance capabilities of commercial drivers.* Because of the severity of crashes between large trucks and cars and the delays caused by truck crashes on congested roads, research to ensure the high performance of truck drivers is a major priority.
2. *Highway design for large trucks.* The choice of design vehicle is critical to many geometric design guidelines used by highway engineers, such as sight distance requirements for passing and stopping and provision of adequate turning radii at curves, intersections, and ramps to prevent vehicles from encroaching on opposing traffic lanes or running off the road.
3. *Evaluation of major truck safety programs.* In addition to the evaluation of the CDL as mentioned earlier, the study recommends the evaluation of MCSAP and the safety review program.
4. *Police capabilities to detect truck safety violations.* Truck safety violations, such as driving with poorly maintained or misadjusted brakes or driving overweight, have the potential to create a far greater hazard in a truck than in a passenger car because of the adverse effects of the greater size and weight of the truck in the event of a crash. Research is needed to determine what combination of enforcement strategies and technology will maximize police capabilities to deter and remove unsafe trucks from the highways.
5. *Truck safety data.* Existing truck safety data are inadequate to determine the magnitude and trends of truck safety problems and to guide actions to reduce crash losses. Several efforts under way, most notably the Center for National Truck Statistics of the University of Michigan Transportation Research Institute, FHWA's MCMIS data base, and the minimum truck crash

data elements to be included in state accident record systems that were recommended by the National Governors' Association, can help sort through the costs and benefits of alternative technologies and determine where they can be most effectively deployed.

The expected benefits from these opportunities can be optimized only by creating partnerships between the government agencies administering and regulating motor carrier programs and the segments of the affected industry groups.

Creative Partnerships

ISTEA provides an excellent opportunity for developing partnerships between federal and state governments and the motor carrier industry. A cooperative government and industry venture can provide oversight to the existing and emerging development, implementation, and evaluation of safety programs. OTA concluded in its report that addressing motor carrier safety issues successfully requires a comprehensive strategic approach (*4*). OTA found that the division of responsibility for different facets of roadway, vehicle, and driver issues among multiple agencies hampers problem solving. OTA also concluded in its study that DOT agencies need to coordinate in collecting and analyzing data, conducting research programs, and developing regulatory proposals. The OTA study considered government agencies only. Industry must be included as an equal participating partner. The coordination with motor carriers and government is becoming increasingly important in the light of emerging large truck issues and technology to address these issues.

Yet there still exists an uneasy alliance between government agencies and the trucking industry in addressing managerial and technical initiatives. This was shown in the federal DOT endeavors toward uniformity in registration and fuel tax, especially in the area of weight-distance taxing mechanisms, and in the early phases of the Heavy Vehicle Electronic License Plate (HELP) program. Some of the barriers to a more cooperative working environment have been broached by the various working groups and Motor Carrier Advisory Boards that came into existence since the Motor Carrier Act of 1980. This is especially true regarding the industry and government in the case of the HELP program, and between federal agencies on certain issues, commercial vehicle operations (CVO) in particular. But institutional barriers still exist in federal and state governments and within the various industry groups. These issues must be resolved if significant enhancements to motor carrier safety are to be attained.

One initiative that may overcome these barriers is the IVHS technology being developed. A major functional area of IVHS technology is CVO. Commercial vehicles are using automatic vehicle location, tracking, and two-way communications; routing algorithms for dispatch; and in-vehicle text and map displays. These technologies can expedite deliveries, improve operational efficiency, and increase safety. Both industry and government acknowledge that the goals of the CVO can be met only with public-private partnerships.

These CVO goals are transparent state borders and electronic commercial driver and vehicle inspections. Transparent state borders refer to an electronic network that would allow commercial vehicles to travel from one state to another as smoothly and as easily as passenger cars. Compliance with registration, licensing, and permits would be verified electronically. Mileage could be reported to the states automatically. Electronic commercial driver and vehicle safety inspections would be used to verify electronically information such as a vehicle's Commercial Vehicle Safety Alliance (CVSA) inspection decal and a driver's CDL. Achieving these goals will require the resolution of many issues in technology, human factors, and standardization. However, the most fundamental issues to be resolved are institutional (*12*).

FHWA is addressing this obstacle by funding a CVO Institutional Issues Study. FHWA will help participating states (several states are grouping together and pooling their funding and resources) to establish a multiagency working group to identify and study how CVO technology can be implemented. A major task in this study is to "identify the types of institutional (organizational, legislative, regulatory or administrative) issues that would impede or prevent the application of IVHS technology and what institutional changes would need to be made to

resolve these issues." The Midwest Transportation Center through Iowa State University has developed a detailed work plan for such an effort for use in Iowa. This study addresses CVO implementation, but its design is readily adaptable to motor carrier safety issues in general.

The institutional issues become acutely important with the imminent international flow of commerce fostered by the North American Free Trade Agreement (NAFTA). NAFTA affirms the commitment of Canada, Mexico, and the United States to promote employment and economic growth in each country through the expansion of trade and investment opportunities in the area of free trade. NAFTA eliminates all tariffs on goods originating in the three North American countries in order to enhance the competitiveness of Canadian, Mexican, and U.S. firms in global markets. The objectives of the agreement must be compatible with provisions that protect the environment of North America. Of particular interest to this paper are the provisions removing land transportation barriers between the NAFTA countries and for the establishment of compatible technical and safety standards for land transport.

Six years after NAFTA goes into effect, each of the three countries will allow cross-border access to its entire territory to trucking firms from the other two. Consistent with their commitment to enhance safety, the NAFTA partners will endeavor to make compatible, over a 6-year period, their standards-related measures with respect to motor carrier operation, including

- Vehicles, plus equipment such as tires and brakes, weights and dimensions, maintenance and repair, and certain aspects of emission levels;
- Nonmedical testing and licensing of truck drivers;
- Medical standards for truck drivers;
- Standards relating to the transportation of dangerous goods; and
- Road signs and supervision of motor carrier safety compliance.

NAFTA includes a review process for the effects of liberalization in the land transportation sector. Five years after the agreement is in effect a committee of government officials of the three countries will review any specific problems or unanticipated effects of the agreement on each country's motor carrier industry. The results of these consultations will be forwarded to the NAFTA Trade Commission for appropriate action. The review process of NAFTA includes government officials from the three countries and provides the framework for creative partnerships between and among agencies and motor carriers for all North America.

Government officials and safety experts have long sought ways to achieve a responsible balance between ensuring highway safety and facilitating the flow of commerce. Partnerships, between and among government and motor carriers, that will address institutional barriers to accomplishing mutually agreed objectives can provide that needed balance. In an effective partnership, each party involved must receive a recognizable gain. If this gain exists and is recognized, the next most important factor is the commitment of high-level officials of the organizations involved to set goals and ensure that the agreed-upon program objectives are met. This statement sounds simplistic, especially in the light of the complexity of the issues and the fragmentation of government and industry organizations involved. It is based on the assumption that carriers, large and small, are generally interested in safety. But they will measure investments in safety innovation, whether in new equipment or driver safety programs, against tangible economic rewards. Government agencies must keep this in mind when enacting, developing, and enforcing safety regulations.

On the other hand, government requires the cooperation of the motor carrier industry to effectively meet its regulatory mandates. The past decade has witnessed an era of shrinking resources in the nation and in the world. Productivity is a key term in many areas, and commercial trucking is no exception. Improving productivity from the standpoint of both government agencies and the trucking industry is impossible without a recognition of the interconnection of the industry's financial performance and government regulation in the areas of economics, registration and licensing, taxation, and safety.

The motor carrier industry servicing North America has four major points of contact with the governments of the states and provinces: vehicle registration and driver licensing, highway

use taxation, safety, and economic regulation. In the United States, the Motor Carrier Act of 1980 effectively eliminated economic regulation and ISTEA is mandating administrative uniformity of existing state economic regulation as it affects interstate commerce. ISTEA provides for uniformity in registration and fuel tax collection. An important provision in ISTEA that can have far-reaching effects on safety management is for a feasibility study for the CVIS, described earlier. Information from CVIS, if links are provided, can be integrated with information from Safetynet and MCMIS. The implications for administrative efficiency and safety are enormous. The ability to identify illegal operation for registration and taxation can result in more equitable distribution of highway cost responsibility. By linking safety to these systems the safety enforcement capabilities would be greatly enhanced. If the CVIS becomes a reality (FHWA must report on its feasibility by January 1, 1995), it, in conjunction with information from CDLIS, Safetynet, and MCMIS, would provide an integrated decision support system for a strategic partnership between industry segments and government for motor carrier safety management.

Achieving the safety benefits suggested in this paper would require the implementation of policy initiatives by federal, state, and local governments that would establish long-term partnerships. Such partnerships would involve mid-level, and some top management, representation of government and industry organizations. These partnerships would then be responsible for setting goals for functional agencies in government and industry and would require progress reporting systems on the strategic objectives implemented to achieve established goals.

The implementing agencies would develop the strategic objectives, cooperatively, with the use of information technology of shared data bases, hardware, and software devices. The implementing agencies would report back to the strategic management partnership on their progress, successes and failures, and suggested adjustments to goals or objectives. This process suggests a highly integrated environment of management and technology, without which the benefits hoped for by government and industry in meeting the goals of ISTEA and the economic competitiveness of the nation will not be optimized.

Motor carrier safety regulation is protective regulatory policy. In the case of protective regulatory policy, it is usually the lowest organizational units of Congress and the executive branch that address the full range of issues both internally and with each other. However, when dealing with broad questions such as creation or alteration of regulatory powers, virtually no final decisions are made at these levels. Inevitably the issues are taken to higher organizational levels for continued discussion and resolution. This escalation of issues does not automatically mean final decisions will be reached. In fact, many regulatory issues are debated over and over in much the same terms for many years. But often resolution does not occur and conflicts continue (*13*).

Policy initiatives, such as the CVO initiative, should allow much of the regulatory conflict resolution to partnerships. Doing so could achieve a higher-level optimization toward meeting objectives of the mission of both government and industry. The author suggests neither that government abandon its mandated regulatory responsibilities to the industry, nor that the regulatory agency become "captive" to the industry to the extent that there is self-regulation with governmental blessing, but instead that government and industry work cooperatively toward mutually agreed goals that are developed in trust and concert with each other's established mission.

It is a sad fact of bureaucratic life that it is often easier to achieve cooperation between jurisdictions than it is to achieve the same degree of cooperation among the various agencies within a jurisdiction or department. The fragmentation in the motor carrier industry suggests that this is probably also true in this sector. To get these two groups together in a truly effective partnership may sound impossible or, at best, naive. However, the potential productivity and safety gains demand that this concept be investigated fully and that these obstacles be overcome as necessary. The development process of these systems and their implementation and use will go far in removing or bypassing these obstacles as jurisdictions and industry focus on mutually established goals.

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Summaries of Panelists' Comments

Thomas A. Glascock III, *Burlington Industries, Inc.*

Thomas Glascock agreed with several points raised by Zogby's paper, particularly the overriding theme that government and industry must work together in addressing safety issues. He agreed with Zogby's comment that carriers large and small are interested in safety but will measure any benefits from proposed safety regulations against tangible economic reward; government must keep this in mind when designing regulations.

Glascock said that legislators have come to understand the public's intolerance for the threat presented by unsafe trucks and drivers and even the perception that the industry lacks commitment to safety. The public's readiness to sue has made safety a higher priority for fleets because of the high stakes involved if an accident occurs.

What causes accidents? asked Glascock. It is typically not the technical aspects of truck or road design but the more subtle human factors that have the biggest effect on safety. The attitude of the driver, helped or hindered by working conditions, has a huge impact on safety. Even though almost all accidents can be attributed to one of three things—the truck, the driver, or other vehicles—most are the result of driver error. Until this important human factor is given the attention it deserves, no significant progress can be made toward reducing the number of truck accidents. Improved truck driver performance cannot be accomplished through legislation but will come only through an effective partnership of motor carriers, government agencies, and truck drivers themselves. Until the truck driver is included in the partnership, we will not make the progress in highway safety that the public wants, Glascock stated.

Edith B. Page, *Bechtel Corporation*

Referring to Zogby's paper, Edith Page also commented on the number and variety of players in the transportation and motor carrier game and how this can lead to fragmented responses from both government and industry when addressing important

issues such as safety. Determining the appropriate balance in providing economic incentives to an operator, large or small, becomes very complicated, she said, because each group is likely to react differently. Owner-operators view safety incentives very differently than larger companies because they do not have the resources to make public responsibility a priority; whereas larger companies have much more visibility on the road and must factor in public perception.

Among the salient issues surrounding the safety question are the following (note that the different sections of the U.S. Department of Transportation have responsibility for each of the three):

- Are longer combination vehicles inherently unsafe, or do highway design and infrastructure conflict with their design? Changes to highway design are much harder to effect than changes to truck design.
- Driver training.
- Standards, which pertain to highway design as well as to truck design. Emerging and evolving technologies make developing highway design standards difficult because of the allowances that must be made for the inclusion of new vehicle designs.

Despite the fragmented framework, substantial progress has been made in safety, evidenced by the number of fatal accidents holding constant in the midst of greatly increased vehicle miles traveled by both trucks and cars. Page feels that legislation has prompted some of the new regulation and cooperative atmosphere surrounding safety issues. Because the number and variety of players make forging a compromise difficult, legislation may force parties to the table, she suggested, adding that the new age ahead will see many controversies related to electronic and logistical control.

Peter F. Sweatman, *Road User Research Pty. Ltd., Australia*

Recent Australian initiatives focused on

- Efficiency, which addresses uniformity of vehicle regulations and standards, administrative costs of road transportation, and the increased use of bigger combination vehicles; and on
- Safety: better and more safety-conscious behavior is sought from operators and drivers, especially with regard to speed.

Factors considered important in examining the causes of truck accidents include driver fatigue, speeding, and inattention; vehicle defects and stability; road design, alignment, and delineation; and the number of trucks on the highway.

Countermeasures to be used to prevent accidents are difficult to identify because crashes often involve many factors. The effectiveness of countermeasures is hard to determine because they are sometimes remote from the site (e.g., rest areas).

Australian motor carriers have undertaken several measures to improve safety, including better driver selection and training; better driver management, with the provision of incentives; introduction of speed limiters; and safer vehicle configurations, such as the B-train double design.

Current safety developments in Australia include the following:

- Regulatory reform through the National Road Transport Commission,
- National forum to involve all transportation operators,
- Consideration of operator licensing, and
- Limited introduction of quality assurance contracts between the operator and road manager.

WORKSHOP SUMMARIES

Carrier Safety Responsibilities: Prescription for Self-Help

Kenneth A. Thompson, *Yellow Freight (retired)*

This workshop focused on carrier safety responsibilities and on ways in which federal and state governments and carriers can work together to enhance safety. A major emphasis was the small, private carrier who often lacks knowledge of safety regulations and, compounding the problem, is typically unconcerned about this ignorance.

Discussion

The actual role of the driver in accidents was the first topic discussed. Several participants noted that although driver error should not be minimized, the driver is not the only responsible party; the public also needs to be better educated about how trucks actually work and how other vehicles can safely interact with them on the road. In this regard, the "Share the Road" program and similar educational efforts are positive and necessary steps.

The looming problem of safety and the small-fleet owner-operator was discussed next. At least 80 percent of all carriers are small, private operators; often, trucking is a secondary line of business for them. Many small carriers have no safety ratings; thus, they have no incentive to learn more about safety or to demonstrate safe operations. Unlike manufacturers, who are familiar with International Standards Organization (ISO) 9000 and other regulations that require them to keep records, many small operators are unaware that they actually are motor carriers, and consequently they keep no safety records or maintenance files. Although they want to succeed in their businesses, small carriers do not want to take valuable time off for training. Lacking business-management sophistication, they tend not to perceive safety as linked to profitability—as do the big carriers (e.g., United Parcel Service), who understand the relationship between safety programs and fuel efficiency, reduced accidents, and so on. Participants noted that for the larger carriers, a more "self-regulating" approach to safety may be appropriate: that is, instead of complicated and time-consuming inspections and forms, the carrier, to satisfy regulations, could give evidence of a sound safety program. For the far more numerous and varied small carriers, a more prescriptive and proactive approach is needed to ensure compliance.

The problem of how to reach and educate these carriers persists, however. One possibility is to reach the small operator through the customer supplied by that operator, which may be a large company familiar with safety regulations and eager to have its contractors adhere to

them. Another possibility is to use the carrier certification process to ensure that all carriers receive some training analogous to the commercial driver's license (CDL) process, which has brought truck drivers to at least a minimal level of knowledge.

The issue of how carriers themselves perceive safety regulations was also discussed. FHWA participants noted that many carriers feel that regulations impede safety and efficiency; that is, regulations make it difficult for carriers to run their businesses flexibly yet safely. Carriers point out, for example, that safety inspections could be made compatible with preventive maintenance inspections and that truckers are put out of service too hastily for small, readily corrected infractions.

The question of hours of service, discussed next, was generally agreed to be a thorny one. There is only anecdotal evidence on the effects of driver fatigue and on correlations of fatigue with the percentage of accidents overall. In Europe, hours of both driver service and rest are stipulated; however, definitive correlations with safety have not been made (and in any case, haul distances are generally shorter). In the United States, the problem with the 10-hr rule is its vagueness; gross violators should clearly be sanctioned, but it is less clear what should be done about the driver who has driven only slightly longer than 10 hr when an accident occurs. More study in the general area of driver fatigue is clearly needed.

Recommendations

FHWA is piloting a program in which small carriers can go to a local office and receive training in truck safety and operation. This program has been a positive counterpoint to truckers' perceptions of FHWA's role as giving them safety ratings (often poor) rather than providing assistance in improving their safety records. Participants agreed on a recommendation that Motor Carrier Safety Assistance Program (MCSAP) funding be made available at the state level for this type of training, which is likely to continue having positive effects. Some states (e.g., Maryland, Pennsylvania) have toll-free information lines for truck drivers or publish truckers' handbooks and maps showing congested areas and construction sites. Participants agreed that because these initiatives can reach independent owner-operators, they are valuable and should be pursued further. A further recommendation, therefore, is that the Commercial Vehicle Safety Alliance (CVSA) or FHWA acts as a clearinghouse for information on such programs and their effectiveness.

Finally, participants discussed and agreed on the need for further research on the demographics of carriers (i.e., information on carrier size and operations) and its differential role in safety performance. This research would be extremely useful in light of the number of small, independent carriers nationwide—a population whose level of awareness about safety requirements is considerably below that of the large fleets.

North American Harmonization of Operating Safety Requirements

Steve Anders, *Kentucky Department of Vehicle Regulation*

Steve Anders presented an overview and brief history of the efforts to harmonize North American operating safety requirements, including pertinent U.S. legislation as well as past and present regulatory efforts in Mexico, the United States, and Canada. Many efforts and forces are working toward harmonization, such as MCSAP, the North American Free Trade Agreement (NAFTA), and various intelligent vehicle-highway system (IVHS) projects. Additional group involvement comes from the interstate trucking industry, the American Trucking Associations, the American Association of Motor Vehicle Administrators, CVSA, and AASHTO. These cooperative efforts and forces resistant to harmonization, such as certain state and local political and economic imperatives, were topics for review during the workshop.

Discussion

The work group identified the following accomplishments with regard to harmonization:

- The general compatibility of intrastate safety regulations and Federal Motor Carrier Safety Regulations within the United States,
- The standardized training and inspection procedures for North America as developed by CVSA and the Transportation Safety Institute, and
- The standardized out-of-service criteria adhered to by CVSA jurisdictions in Mexico, the United States, and Canada.

The work group noted the following items as work in progress:

- A uniform fine and penalty structure for safety violations (developed but not yet universally used);
- Full participation in MCSAP by all U.S. states;
- Consolidation and coordination of various safety-related informational systems: Motor Carrier Management Information System, Safetynet, Fatal Accident Reporting System, Commercial Driver's License Information System;
- Inclusion of inspection and safety components in IVHS projects; and
- Creation of transparent international borders for safety regulations and vehicle inspections.

RECOMMENDATIONS

A series of questions and recommendations for North American harmonization of operating safety requirements generated by the work group began with agreement that it is necessary and desirable for state safety regulations in the United States to be harmonious with or equivalent to the Federal Motor Carrier Safety Regulations. However, the creation of transparent international borders, with regard to commercial vehicle safety, should proceed concurrently with each nation's effort to standardize regulations within its own political subdivisions.

Second, the work group urged the motor carrier safety establishment to continue exploring strategies and technologies that address inspection and safety components for IVHS projects. This charge for further research was made after recognizing the absence of an inspection/safety component for the HELP/Crescent and Advantage I-75 IVHS projects and with the expressed intent of the I-80 project to include such a component.

A third recommendation was for a feasibility study for the creation of a trilateral Motor Carrier Safety Commission made up of representatives from Mexico, the United States, and Canada. The commission would address motor carrier safety issues concerning the signatories to NAFTA and would study the feasibility of creating an international "Super MCSAP" to be jointly funded by the three national governments.

Finally, the following question was posed: given the proliferation of motor carrier identification systems throughout the various provincial, state, and national governments, should a unique national or multinational motor carrier identification system be developed to facilitate the efficient use of motor carrier information systems?

Enhancing Driver Skills and Performance

K. Michael O'Connell, *Collier, Shannon, Rill and Scott; Professional Truck Driver Institute of America*

Workshop leader Mike O'Connell began the session with a discussion of the impact of the commercial driver's license (CDL) on commercial driver training and a brief overview of the history and activities of the Professional Truck Driver Institute of America (PTDIA). The PTDIA has developed a 147-hr core curriculum for entry-level truck drivers that is based on FHWA standards developed in the 1970s; PTDIA has also developed specialized curricula for other uses. The group monitors and certifies training throughout the country and currently has certified courses in 21 states.

With the advent of CDL requirements, driver training has taken on a new dimension. Courses are increasingly designed to train drivers only to pass CDL exams rather than to provide comprehensive driver training. Additionally, failure to provide "standardized" training has become an issue in liability litigation. Increasingly, plaintiffs are alleging that motor carriers have failed to provide adequate training.

Discussion

According to insurance industry statistics, nearly 90 percent of trucking accidents are the fault of the driver, and most drivers involved in accidents have not received any type of driver training. Although these data might indicate an obvious need for increased and widespread driver training from a safety perspective, several speakers raised the larger issue of whether all segments of the trucking industry are willing to invest in extensive driver training. One speaker stressed the need to identify factors other than training that lead to accidents.

Workshop participants discussed the most effective means of ensuring proper entry-level training; one participant suggested federal regulation of training. Participants emphasized that follow-up refresher training (including specialized training for specific driving tasks and for new technologies) and career training are also very important, although conflicting data exist about the effectiveness of such training. It was suggested that a career path be created for drivers and that alternative jobs (e.g., dispatcher or driver ombudsman) be developed to encourage drivers to look on their jobs favorably.

In line with the issue of career training, workshop participants also discussed the reasons that people become truck drivers; several speakers stressed the importance of encouraging people to aspire to this profession. One way to encourage young drivers might be to develop a

career path beginning in high school. Some European countries have apprenticeship programs for truckers; the U.S. Department of Labor has also developed a commercial driver apprenticeship program.

One speaker reminded participants that particular incentives and disincentives may carry greater weight with a driver than concepts learned in even the best training course. This point led participants to discuss defining driver profiles and preemployment screening procedures, which many large carriers are already doing. The group reached consensus on one point: passing the CDL exam is not adequate evidence of effective driver training.

RECOMMENDATIONS

Workshop participants recommended action on the following items:

- More research must be conducted to determine the characteristics of safe and unsafe drivers.
- FHWA and other organizations should continue to study the types and amounts of driver training received by all truck drivers, especially those involved in accidents. The relationship between the quality of training received (types of training vary widely) and accident experience in the early years of driving should also be studied.
- Organizations involved in driver training should focus on developing standardized training for entry-level drivers; ongoing, specialized refresher training programs should also be developed for experienced drivers.
- The standards originally developed by FHWA and implemented by PTDIA are the best current efforts to accomplish high-quality entry-level driver training.
- Carriers should hire drivers trained in courses certified as meeting the FHWA/PTDIA standards.
- FHWA should encourage public-private consortia to study issues and implement strategies for promoting standardized entry-level driver training. These issues include developing driver screening procedures, determining the most important components of training, and establishing recommended practices and means to evaluate their use.

Harmonization of North American Size and Weight Standards

Susan J. Binder, *Federal Highway Administration*

The session focused on the truck size and weight research and policy direction needed to enhance free trade among North American partners without undue infrastructure, safety, or modal impacts. After a brief overview of the differences among the three parties of the North American Free Trade Agreement (NAFTA) and the available processes for harmonization, the group brainstormed concerning the five policy-oriented sets of issues set out in the following.

Goals

What can be achieved under NAFTA harmonization? Although it was said that "the NAFTA tail might be wagging the size-and-weight dog," a range of alternatives was identified. Generally arrayed from less to more ambitious, they were as follows:

- Knowledge. Elicit feedback concerning the content of the three countries' regulatory regimes and the performance of cross-border transportation systems.
- Facilitation of movement (including facilities and highway design and regulation). The sentiment was expressed that this should be the prime goal ("the first step") because it drives all other considerations.
- Equity across countries and modes of transportation or expanded markets for trucks and trailers. The relevance of modal equity to international trade was questioned.
- Improved efficiency in transportation and motor carrier fleet design and operation. Given boundary conditions and constraints set by the parties, commercial vehicle use should be optimized.
- Safety. Harmonization could be used not only to avoid safety degradation but also to improve commercial vehicle safety.

Involvement

Alternative mechanisms for attracting wide participation in NAFTA harmonization, especially by states and the various components of the transportation industry, were identified. It was

asserted that industry has already been told that they have been effectively shut out of the process. Susan Binder responded that even though industry does not necessarily have to be at the table to make a significant contribution to the process, a mechanism is being developed to ensure its input. She noted that NAFTA harmonization does not officially begin until January 1994.

The range of methods to involve all interested parties is illustrated by the following questions: Is NAFTA the best catalyst for setting international size and weight standards? Is it realistic for representatives of the full range of relevant interests to sit directly at the negotiating table? Can a group be assembled that fairly represents the public interest? Is a formal federal advisory committee necessary? Could the public provision of a formal "paper trail," such as advance or follow-up notices for comments in the Federal Register, accommodate the need for inclusion? Would less formal canvasing of state and industry concerns accomplish this goal? Would the opportunity to react be satisfactory for parties outside the federal government? Should independent coalitions that are developed in connection with certain transportation corridors be given special standing? It was suggested that the public would be represented by the sum of the parts of participants and that a process to involve all parties might be modeled after the Road and Transportation Association of Canada.

RECOMMENDATIONS

Suggested approaches to effect harmonization included the following:

- Either on the basis of existing operations and regulations or by starting clean, establish recognized NAFTA vehicles. These could begin with a set of minimum common standards or lead to completely new standards, on the basis of performance specifications.
- Create NAFTA corridors with size and weight exemptions or incentives. Closely allied were regional options, including permitting approaches.
- Seek quid pro quos by combining liberalized federal standards with a package of additional safety and revenue elements.

Considerable disagreement centered on the temporal element in the strategy. An interim NAFTA vehicle was contrasted with a longer-term view of future trade. Enforcement and dispute resolution mechanisms were mentioned as being closely allied to strategy.

Means

Participants identified various means by which harmonization negotiations could contribute to more compatible continental standards. NAFTA negotiators could aim toward (a) establishing criteria for evaluating standards by the parties; (b) developing options for changes in truck size and weight standards; (c) forming a consensus on international and national impacts, with a strong technical base; (d) forming a consensus among the negotiators on preferred options on the basis of those impacts; and (e) making specific recommendations for subsequent action by the parties.

Research

Research needed to advance policy goals could include the following:

- Credible forecasts of traffic and trade impacts (including an understandable synthesis of findings across models that are clear about their assumptions) to facilitate informed debate. Evaluations of prior traffic and trade impacts of size and weight changes would be useful.

- Clear intermodal and intramodal diversion estimates of various policy options, although some participants objected to government-sponsored "market share" analysis.
- Cost-benefit analysis that incorporates the perspectives of shippers and carriers as well as public stewards and that recognizes sunk capital costs.
- Quantification of the inherent trade-off implicit in the status quo, including current performance design standards. Determine the public's tolerance levels for suboptimal performance.
- Inventory of physical barriers or bottlenecks to identify and scale industry desires and government interest.

Common to all these issues was the need to balance seemingly competing concerns: industry sectors and modes; domestic and international trade contexts; federal, state, and regional environments; and uniform and nonuniform systems. The challenge will be to keep our eyes on constructive progress, summarized Binder. Early outreach and goal setting will be crucial to achieving such a balance.

HIGHWAYS FOR EFFICIENT AND SAFE GOODS DISTRIBUTION

Keynote Address

Francis B. Francois, *American Association of State Highway and Transportation Officials*

Borrowing a phrase from the Founding Fathers, Francis Francois maintained that there are certain "self-evident truths" related to highways and the motor carrier industry. He used this framework to introduce his topic, the physical aspect of highways.

First, highways in the United States are a prime concern of the individual states and of AASHTO because (a) they are the backbone of the transportation system and industry, and (b) states have primary responsibility for them. States own, maintain, and operate the nation's highways; decide where new highways should be built; and pay 50 percent of the combined costs of capital construction, maintenance, and operations. Local governments contribute about 30 percent of the total highway costs, and the federal government pays about 20 percent. For capital construction costs alone, the federal government share is 40 to 45 percent.

Second, highways can exist without the motor carrier industry, but the motor carrier industry cannot exist without highways. The growth of the motor carrier industry has paralleled the growth of highways, particularly since the development of the Interstate highway system. Likewise, the efficiency of the motor carrier industry depends on efficiency of the highway system. The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) proposes an extensive National Highway System (NHS) with uniform standards nationwide; this system will be critical to the U.S. economy in light of developments in the European Community. The highway community and motor carrier industry must work together to bring about the NHS.

Third, the use of highways simultaneously by passenger cars and heavy trucks creates conditions that place limitations on the motor carrier industry. Public perceptions about trucks often drive policy, even when those perceptions are false. The railroads have an edge over motor carriers in this area because mostly they no longer carry large numbers of passengers; therefore, they have been able to develop the rail system for optimum freight-carrying capabilities.

Fourth, when viewed from both a national and international perspective, trucks are dominant over other freight transportation modes because of their flexibility. For example, in Europe trucks can move more freely across national borders on fairly uniform highway systems, whereas each country has a separate rail system. In the United States, where the railroad system is uniform, the trend is toward intermodal transportation; however, this trend will not decrease the importance of trucks in reaching areas that other modes of transportation cannot reach.

Fifth, important reasons will compel all parties who have a stake in the motor carrier industry—truck designers and manufacturers, highway engineers, and truckers—to work together in developing the NHS called for by ISTEA. The states are putting together a map of the proposed NHS network; however, its establishment by Congress is not guaranteed, and those involved must work together to facilitate the process.

Finally, highway engineering has moved well beyond the bounds of civil engineering. Today's highway engineer must understand the total impact of a proposed highway on such diverse areas as the surrounding environment (wetlands, etc.), air quality, noise, and traffic management. From the existing system they must also be able to provide highways that offer the highest efficiency. Because the advent of intelligent vehicle-highway system (IVHS) technology will help accomplish this goal, highway engineers must be able to work in this technological environment as well.

Highway engineers are concerned about better pavement and higher-quality roads, pavement-truck interactions, and road geometry. According to Francois, more attention should be focused on system concepts (e.g., the placement of rest areas, access to roadways, etc). The transportation community also needs to focus on the implementation of IVHS and related technologies that will make the highways and motor carrier industry more efficient.

In closing, Francois offered four observations on the future of highways and the motor carrier industry. First, the success of NAFTA will largely depend on highways and motor carriers because together they form the backbone of freight movement. Second, making highways progressively safer and more efficient will have a direct bearing on the prosperity of the people. Third, research is needed in several areas so that better trucks and highways can be built. Last, adequate funding must be found to accomplish all of these goals.

Highways for Efficient and Safe Goods Distribution

C. Michael Walton, *University of Texas at Austin*

Michael Walton identified four key issues to evaluate when designing highways for the improvement of North American economies:

- Productivity,
- Safety,
- Pavement, and
- Bridges.

Domestic Freight Transportation Issues

Walton identified 13 issues that require new or further research:

- Characteristics and growth of freight demand;
- Efficiency, safety, and public policy for rail and truck competition;
- Institutional arrangements and compatibility of federal and state truck regulations;
- Collection, use, and adequacy of user fees;
- Long-term availability of highway and bridge capacity;
- Transportation safety, including perceptions and operator behavior;
- Productivity benefits of truck size and weight changes;
- Energy consumption and air quality;
- Highway geometrics and truck compatibility;
- Enforcement;
- Pavement construction alternatives to reduce life-cycle costs;
- International practices; and
- Rail disinvestment.

Influence of Increased Truck Size and Weights on Geometric Design Principles

- Stopping and passing sight distance,
- Pavement widening on curves,

- Critical length of grades,
- Lane and shoulder widths,
- Minimum design for sharpest curves,
- Width for turning roadways,
- Sight distance at at-grade intersections, and
- Median openings.

Opportunities for Improving Truck Safety

- Equipment specifications, operating practices, and driver training;
- More stringent driver controls;
- Improved truck controllability;
- Upgraded geometric design of highways;
- Dedicated, comprehensive safety management by trucking firms through monitoring and training of drivers, maintaining equipment, employing safety professionals, acquiring accident data, and considering safety versus short-term cost; and
- More effective enforcement of truck safety regulations.

Issues

In the bridge area, the questions are as follows:

- What is the long-term capacity of the highway and bridge system?
- What is the quality of data on bridge conditions?
- Are bridge posting and design practices too conservative?
- Are larger trucks eroding safety margins?
- Does conservatism in design hide a reserve of unused load-carrying capacity in bridge systems?
- Could estimated replacement costs be reduced by better screening for actual capacity?

Vision of Intelligent Vehicle-Highway Systems

Commercial vehicles operate on North American highway systems with the same ease as passenger vehicles while ensuring regulatory compliance and user safety.

Goals of Intelligent Vehicle-Highway Systems

- Benefit North American industry through increased productivity for commercial vehicle operations,
- Increase efficiency for government,
- Improve traffic safety and highway operations,
- Continue technology development and implementation, and
- Enhance industry and government partnering.

Safety

- Real-time driver and vehicle safety monitoring,
- Hazardous materials tracking,
- Site-specific highway warning systems, and
- Automatic mayday capability.

Productivity

- Electronic permitting,
- Electronic logbook and fuel tax reporting,
- Automatic credential and weight checking,
- Real-time information systems, and
- Comprehensive data collection for planning.

Near-Term Deployment

- Weigh in motion,
- Automatic vehicle identification (AVI),
- AVI and automatic vehicle classification (AVC),
- Automatic vehicle location systems, and
- Static network routing and scheduling.

Middle-Term Deployment

- Vehicle safety monitoring system for driver use,
- Highway speed toll collection (AVI and AVC),
- Automated vehicle and driver credential reporting (AVC),
- Highway safety warning systems (including ramp radii, height limits, and grade speeds),
- Computerized fleet tracking and dispatching,
- Automated hazardous materials identification and location,
- State line beacon network, and
- Dynamic or combined static-dynamic network routing.

Longer-Term Deployment

- Electronic tax and permit systems, and
- Automated vehicle and driver condition monitoring and reporting.

Keys to Successful Commercial Vehicle Operations Program

- Partnerships;
- Joint goals and plans;
- Costs, benefits, and market; and
- Solving institutional problems.

Summaries of Panelists' Comments

John R. Billing, *Ontario Ministry of Transport*

John Billing noted that the challenges implicit in discussions of safe and efficient goods distribution are less a matter of technology than of decisions about how much efficiency, productivity, and so forth is desirable. He then observed that a discontinuity between the apparent public acceptance of a major safety problem—namely, the 50,000 vehicle-related fatalities that occur annually in North America—and public concerns about large trucks, typically perceived as unsafe. The public also tends not to accept that larger trucks mean fewer trucks on the highway. In short, there is a credibility barrier to be overcome.

Billing observed that the cost of bridge maintenance and renewal is a major institutional impediment to any significant increase in allowable gross weight for trucks. He noted that these costs were estimated using conventional methods of analysis, which may not always represent the actual behavior of bridges under load, and cited the impact factor as an example. A formula based on span length was developed in the 1920s from earlier railway standards, when the main issue was the difference between solid and pneumatic tires. The committee that developed the formula did not, in fact, see any relationship between bridge response to a moving vehicle and span length, yet the formula remains today, more than 60 years later, in AASHTO's bridge design code.

Billing noted Horne's example given yesterday—that Navistar's engineers had been able not only to meet emission targets that were initially considered "impossible" but to produce a better engine while doing so. The challenge led to a better understanding of the issues and technology and produced a very desirable result. Billing suggested that a policy decision to increase gross weight would be a similar challenge to bridge engineers. Their initial response would probably simply reiterate the cost and risk. However, if the challenge were pressed, the engineers could find innovative ways to respond. Some work could be reprioritized, and another designated highway system might be developed that would allow the higher weights and could be extended as freight flows demanded and budgets allowed.

The key to achieving this goal would be a realistic assessment of the actual load capacity of existing bridges for which Canada's *Vehicle Weights and Dimensions Study* provides a model. Before this study, the provincial pavement engineers could not agree on the mechanism for assessing the extent of pavement damage by axle group loads. A series of identical tests was conducted on similar road structures in different provinces, and the results allowed the pavement engineers to reach agreement on uniform allowable axle group loads for all provinces. Billing suggested that perhaps the United States—to allow a consistent approach by the states—would benefit by a series of bridge tests to assess the safe capacity of similar bridges in different regions against potential increases in allowable gross weight.

Billing summarized by noting that NAFTA offers large opportunities. Its potential will not be fully realized, however, until new and innovative approaches are devised for designing a safe, efficient highway system that will serve the needs of the new North American economic union.

Hank E. Seiff, *ATA Foundation, Inc.*

Hank Seiff suggested that motor carriers and highway and bridge builders think of themselves as being in a customer-supplier relationship. To get the most out of such a relationship, the customers (shippers and motor carriers) and suppliers (federal, state, local, and regional governments) must understand each other's needs, capabilities, and limitations. To this end, highway and bridge engineers should receive training in the needs of their customers—the truckers—and truck engineers in the capabilities and limitations of their suppliers—the highway and bridge builders.

This training should be included in the university engineering curriculum and be available as continuing education. FHWA should consider institutionalizing and subsidizing such training to ensure that state highway and bridge engineers will attend.

In the area of size and weight, it is generally agreed that increasing the size and weight of trucks is the most efficient way to move freight. Larger and heavier vehicles also decrease noise, use less fuel, reduce gaseous emissions, and improve safety (because of a reduction in the number of vehicles on the road). Seiff urged members of the trucking industry to work with highway and bridge engineers in developing a systems approach to maximizing efficiency and reducing costs in the movement of freight.

Calvin G. Grayson, *University of Kentucky Transportation Center*

Calvin Grayson opened his remarks by noting that he had never seen a greater opportunity in transportation than the one that exists with intelligent vehicle-highway systems/commercial vehicle operations (IVHS/CVO). With the development of new technologies, however, come a number of organizational and jurisdictional challenges. The notion of "transparent borders" within the United States and an increasing emphasis on multistate, multijurisdictional, public-private, and academic partnerships offer not only the potential for conflict but also a rare chance for true cooperation among all partners. Such partnerships can lead to increased safety and compliance, greater efficiency, greater simplicity, and improved productivity.

Drawing on his experience with the "Advantage I-75" partnership among six states, motor carriers, FHWA, and officials in Ontario, Canada, Grayson listed a number of ingredients that lead to successful partnerships. These ingredients include an emphasis on cooperation, true commitment to the partnership process, trust among all the partners, and willingness to work together for common goals and objectives. The outcomes of successful partnerships can be measured in time and money.

Grayson challenged symposium participants to demonstrate leadership that will enable the transportation industry to take full advantage of the opportunities presented by emerging technologies such as IVHS/CVO.

WORKSHOP SUMMARIES

Relationships Among Truck Design Features and Pavement Wear

Margaret M. Sullivan, *PACCAR Technical Center*

Margaret Sullivan began the workshop by outlining the following issues for discussion in the context of improving pavement wear: (a) developing a dynamically quiet road-vehicle system, (b) reducing rutting of flexible pavements, and (c) fostering an ongoing dialogue between the vehicle and infrastructure communities.

Discussion and Recommendations

Developing a Dynamically Quiet Road-Vehicle System

Parameters of dynamically quiet road-vehicle systems include vehicle characteristics, axle loads, design innovations (e.g., semiactive suspensions), spatial repeatability, road roughness characteristics, and road maintenance timing. The discussion covered the following issues:

- Design innovations. Optimizing vibration characteristics (minimizing wheel loads, vibration at payload/driver) is important.
- Spatial repeatability. Spatial concentration studies in the United States and Canada are recommended; instrumented pavement needs calibration with instrumented vehicles, and transducer definition is required. An alternative to conventional weigh-in-motion technology may be acoustic or optical signatures of tire loads; research would be required.
- Road roughness. A test method to evaluate road-friendly suspensions is needed. A topic for further research is the relationship of the International Road Roughness Index to dynamic wheel loads.
- Road maintenance timing. State departments of transportation need tools to determine optimum maintenance timing and required initial smoothness to minimize dynamic wheel loads.

The discussion concluded with naming the following topics for further research:

- Is there a mechanism for encouraging road-friendly configurations in vocational applications of trucks?

- Consideration of truck road-friendly features in discussions of NAFTA vehicles.
- Air suspension and irregular tire-wear effects need additional investigation.

Rutting of Flexible Pavement

The discussion of rutting of flexible pavement, an increasing phenomenon, covered the following topics:

- The need for research and implementation of improved pavement mixes (e.g., additives, composites, strengtheners, different designs) to reduce rutting,
- Radial tire characteristics, and
- Steering-axle tires (the most road-damaging tires): can a unique solution be devised for these? Could larger tires be used in a set-back axle configuration? The need to exchange tires between the steering and drive axles must also be considered.

Ongoing Dialogue Between Vehicle and Infrastructure Communities

The discussion of the need for a continuing dialogue between the vehicle and infrastructure communities generated a consensus that a common language is needed for the many parties involved in these issues. Participants expressed support for a continued forum and the need for a "champion," such as a truck manufacturers' association to sponsor the exchange of information and to coordinate research activity among the various parties. Also discussed were the following:

- The need for SAE and TRB to complete definition of the structure for the Commercial Vehicle/Highway Committee;
- The need for motor carrier representation, such as the Maintenance Council of the American Trucking Associations;
- The possibility of rotating the responsibility for meeting coordination in the event an "umbrella" organization is not defined;
- The need for a coordinating approach (i.e., have a coordinating committee rather than a new committee on the issues);
- Potential use of a contractor to coordinate meetings;
- Concern that FHWA does not recognize the need for an ongoing interdisciplinary group on this subject; and
- The Organization for Economic Cooperation and Development research plan for the study of Dynamic Interaction between Vehicle and Infrastructure Experiment (DIVINE). The goals of DIVINE are to improve vehicle and pavement construction and maintenance. The study is expected to provide
  - –New insights for pavement engineers into the design and maintenance of pavements for increased life, and
  - –A common international basis for future harmonized standards, testing procedures, and policy initiatives for heavy freight vehicles.

Bridge Risk Analysis and Motor Carrier Productivity

James G. Saklas, *Federal Highway Administration*

James Saklas presented an outline for discussion of the impact of longer combination vehicles (LCVs) on U.S. highways—specifically, the effect of the nationwide use of LCVs on bridges and productivity. He observed that although some shippers, large carriers, and the American Trucking Associations want the increase in productivity related to LCVs, railroads, safety groups, and many independent owner-operator truckers claim that LCVs are unsafe and costly. Although any decision concerning LCVs will be a political one, it is our obligation to strive for the best analysis possible on this controversial issue.

To highlight this point, Saklas reviewed the Moses work for TRB's *Special Report 225: Truck Weight Limits: Issues and Options*, which concluded that significantly larger combination trucks—including double-bottom trucks weighing up to 59 020 kg (130,000 lb) and larger single-unit trucks—should be permitted because only a small incremental increase in bridge costs would result. Moses' analysis, although based on a valid methodology, assumed a very liberal interpretation of bridge strength: the operating rating as reported in the National Bridge Inventory (NBI). Another study, as reported by Weissman and Harrison in *Transportation Research Record 1319*, analyzed the cost of allowing LCVs on the rural Interstates. Using essentially the same methodology, but assuming the very conservative inventory rating, this study arrived at opposite conclusions. Given their assumptions, both studies are correct; however, the issue is clearly unresolved.

Discussion and Recommendations

Eight key issues were addressed by the work group in an effort to evaluate LCV usage and generate feedback for possible action plans.

- The use of either the inventory or operating rating, as reported in the NBI, is incorrect for estimating bridge excess capacity. This is especially true for the operating rating, where significant errors have been found. The work group proposed the use of NBI data only for nationwide policy analysis (either a multiplier to the inventory rating or incorporation of liveload-to-deadload ratios). For detailed analysis, states must inspect and reanalyze all of their bridges to determine exact strength, which may demand federal dollars. The group also agreed

that a nationwide testing program could be undertaken to measure empirically actual bridge strength and to apply and incorporate detailed risk analysis with cost-benefit analysis.

- Economic evaluation (cost-benefit analysis) needs to be improved before LCV usage can be agreed to on a nationwide basis. For example, we should improve benefit estimation, particularly in the analysis of productivity. The group consensus on this point was to improve communication between truckers and shippers to better estimate LCV motor carrier productivity gains. With the independent owner-operator and LCVs in generally different, noncompetitive markets, there appears to be little problem with LCVs adversely affecting independent owner-operator truckers.
- All life-cycle costs and benefits of LCVs must be considered before they can be allowed. For instance, because social benefits (such as time savings) are considered valid benefits in the evaluation of all highway and transit improvements, then system (social) costs must be considered in the evaluation of LCV usage. The work group noted that these social costs should include the delay, fuel, and pollution costs associated with bridge replacement and major rehabilitation.
- It is useful to focus on particular LCV configurations. In sum, the trucking industry and shippers must get together to promote desirable configurations.
- Most federal specifications on bridge approaches, abutments, lighting, and such—usually required when bridges are replaced—are driven by safety or level of service. Should these requirements be modified? One plan proposed by the work group was to conduct a cost-benefit analysis to see whether nonstructural improvements are worthwhile. The difficulty with this plan is that additional social costs must be considered when these improvements are made in the future.
- If the market develops new technology, bridges might be strengthened with it. A detailed cost-benefit analysis is recommended, focusing on downstream costs and benefits if future replacement is required.
- Questions were raised about who will pay for replacement, major rehabilitation, and strengthening of our bridges and whether a risk-based formula should be developed. Currently, FHWA and virtually all states use a cost-occasioning theoretical basis for cost allocation; therefore, trucks that occasion bridge replacement, as a result of their size or weight, should pay for the entire cost of the bridge.
- The work group also considered the need for more research to derive a bridge formula based on consistent and acceptable risk versus the current use of a misunderstood and misdefined overstress.

Intelligent Vehicle-Highway Systems and Commercial Vehicle Operations

Lance R. Grenzeback, *Cambridge Systematics, Inc.*

Lance Grenzeback opened the workshop session by challenging participants to re-examine intelligent vehicle-highway systems and commercial vehicle operations (IVHS/CVO) in defining future policy and research questions. Workshop participants selected a number of issues that should be addressed more aggressively by all those who have a stake in the development of IVHS/CVO.

Discussion and Recommendations

Workshop participants raised five major issues to be addressed more aggressively by federal, state, regional, and local governments; by private shippers and carriers; and by organizations developing IVHS/CVO technologies.

1. All parties should take a more structured approach that promotes greater private industry involvement in developing IVHS/CVO technologies, including AVI. To get private industry to accept IVHS/CVO technologies, interested parties must clarify the goals and benefits that the technologies will bring to private industry.
2. Ongoing efforts to construct multistate, multientity partnerships in the development of IVHS/CVO should be continued and strengthened. Entities including local law enforcement, state governors, metropolitan planning organizations, and private shippers and carriers must work together to successfully develop and implement IVHS/CVO. One participant suggested that the federal government give preference to multientity partnerships when awarding funds for IVHS/CVO research and development projects.
3. AVI systems for vehicle-roadside communications should be standardized. Standardization should ideally occur on an international scale, at the very least including the parties to NAFTA. To reach a consensus on standardization, however, a constituency must be developed among all affected parties, and a consensus about desired data outcomes from AVI use must be reached. The proper forum for addressing problems of process must also be created.
4. All parties must come to a clear understanding about the purposes of IVHS/CVO and about who owns and who will have access to the data collected. Appropriate attention must be given to issues of industry confidentiality. Additionally, the various governmental parties (at all

levels of federal, state, regional, and local government) must create an atmosphere of trust regarding their aims in accessing IVHS/CVO data.

5. Efforts to raise the political profile of IVHS/CVO among all parties must be strengthened. One participant suggested asking the National Governors' Association to set up a transportation committee. The "selling" of IVHS/CVO must be predicated on evidence of tangible benefits to government and industry, including its use as a tool in measuring and improving productivity.

Operational Regulation of Longer Combination Vehicles

Paul R. Henry, *Oregon Public Utility Commission*

This workshop's participants undertook a sometimes heated discussion of something that accounts for billions of dollars annually and has been debated for years: LCVs. Participants tried to define what qualifies as an LCV, considered criteria for LCV permitting, and discussed route methodology. Little agreement evolved on this issue, which clearly will not be resolved in the near future.

Discussion

The attempt to define LCVs generated many ideas, with most participants willing to include a gross vehicle weight greater than 36 320 kg (80,000 lb) and a 22.88-m (75-ft) length in the definition. It was generally accepted that "LCV" is a misnomer; "special permitted vehicle combinations" appeared to be a more appropriate description to most participants. Work to determine what combinations of vehicles should be embraced under a new, more accurate definition needs to be done.

Permitting was the next topic undertaken. The Western Highway Institute's (WHI's) four-point list of criteria for carrier permits was offered for discussion. WHI promotes the basing of permits on carrier profile, driver profile, equipment reliability and specification, and highways authorized for various vehicle configurations. Environmental considerations may be added. Because it was generally agreed that triples or long doubles are the safest vehicles on the highways, a participant suggested incorporating "expensive but cost-effective" equipment into them, along with substantial economic incentives to use it, similar to what has been done with Canadian B- and C-trains. A carrier questioned what type of equipment and what incentives would be suggested. He argued that his constituency was being allowed no extra weight and was seeing no added productivity in exchange for a lot of equipment being mandated on vehicles that have performed in a manner "nothing short of exemplary" without it.

Another carrier pointed out that safety is not a concern when triples are operated under specified conditions, by specified companies, using specified drivers, on specified routes. This comment shifted the discussion to route assessment methodology, which, in general, participants believe is missing and needs to be developed. It was reported that Oregon is developing such a process because carriers recognize that today's routing evolved without logical inputs or research.

The group was divided on whether there should be a national permitting system. Regional permitting appears to be beginning to work and is being tried in many areas of the United States. An opponent argued that it is unrealistic to think a national system could be developed where so many regional differences exist. An opponent said that getting nationwide approval for triples could be one of the most cost-effective accomplishments for the trucking industries. However, a special vehicle system must ultimately be installed to complement both NAFTA goals and industry profitability.

When asked how countries could cooperate to allow triples under NAFTA, a Canadian representative said that the trucking industry must address safety, environmental, and data problems before it takes an LCV program to the public. He contended that trucking accident statistics must be quantified and qualified. Reliable, aggregate data must be collected before the public would accept triples. Most participants disagreed, arguing that the public's perception stems from the industry's failure to promote the good that it brings into peoples' lives. Even the WHI permitting criteria evolved from what could go wrong; they do not point out the productivity gains that trucks afford the American people.

Recommendations

Development of a new definition for special permitted vehicle combinations, creation of an internationally acceptable special permitted vehicle combination permit, and development of a dependable and creditable route assessment methodology were several group recommendations.

HIGHWAY INVESTMENT FOR COMPETITIVE NORTH AMERICAN ECONOMIES

Highway Investment for Competitive Economies

Paul O. Roberts, *Transmode Consultants, Inc.*
Michael D. Meyer, *Georgia Institute of Technology*

It is a cliché to say that we live in a changing world. However, there is little question that some of the most dramatic changes in the economic structure of the world have occurred during the past decade. The key word in this statement is "world." Never before have financial markets in all parts of the world been linked by near instantaneous communications that allow 24-hr financial transactions or enable manufacturing industries to develop strategies for making and selling products on the basis of which country is best suited to make which parts of the product and where the final markets are located. Trade and economic security issues have begun to surface as key negotiating points among nations. And large trading blocs are forming to take advantage of the efficiencies and productivity enhancements that accompany cooperative ventures.

In this new economic environment, the nations that will prosper in the coming decades will be those having (a) a skilled and educated labor force that can produce the products of tomorrow, (b) an efficient national transportation system over which these products can reach far-flung markets, and (c) an advanced communication network that connects corporate decision making to the balance of the world.

This paper examines the important role of highways, and a continuing investment in highways, in keeping the U.S. economy competitive in this world market. In particular, the recently passed Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) has placed greater weight on freight movement and access to transshipment points in national, state, and local transportation planning and decision making. Within the context of ISTEA, and reflecting the changes in the world economic structure just mentioned, it appears appropriate to ask how the United States should view its National Highway System (NHS), in particular, with comparison to other such systems.

What are the changing transportation needs of our society that must be considered as our nation enters the post-Interstate era of transportation planning and investment? What trade-offs exist between enhancements in motor carrier productivity and system capacity? What other trade-offs exist between these enhancements and the concomitant impacts on the quality of the environment and energy consumption? Finally, how do all of these concerns reflect what we as a nation should do to ensure that a vital part of our economic survival—the mobility of people and goods—remains an asset instead of a liability?

This paper addresses these concerns by identifying five key issues that must be faced by the nation's transportation system designers. Each issue is accompanied by background com-

ments, inputs, and some discussion. Some options are merely straw-man alternatives because posing realistic alternatives is a bigger job than can be undertaken here. The issues are important ones, however, and this paper attempts to begin the public dialogue.

Shifting Production Characteristics of Changing Economic Structure

Global Production Systems

Business needs three things to survive: goods or services to sell, reliable sources of resource supply for these goods, and markets in which to sell. Because there are economies of scale in both producing and distributing many products, the market place in which a given producer attempts to compete has become increasingly larger and more competitive. In this context, "large" is measured in terms of the buying power of the market. Large population centers, for example, attract the interest of producers, leading to their "inclusion" into the market system of that particular producer. The market domain of many producers is becoming the entire world.

The world is rapidly evolving into three major aggregations: Europe, North America, and Asia. The makeup and size of the countries within each group is shown in Figure 1. In each case, the major partners are in various stages of forming closer economic unions that will have dramatic effects on world trade and on the relative competitiveness of the economies of individual countries. These economic organizations will have at their core an examination of how to make transportation between producers and consumers as seamless as possible.

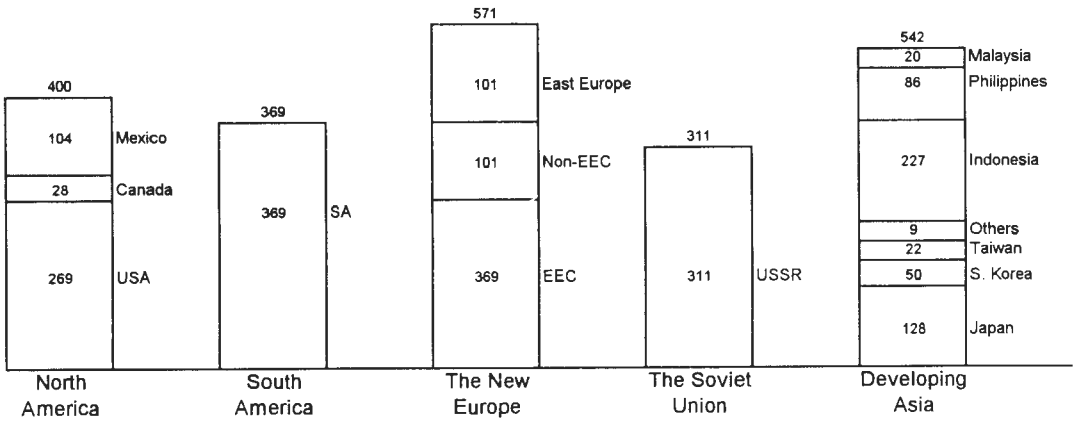

FIGURE 1 Major trading groups (*source: World Bank projections*).

Europe, currently stymied in its efforts to form the European Economic Community (EEC), now has a whole new set of potential partners in the countries of Eastern Europe. Not only can this set of new partners furnish the productive, low-cost labor needed to increase the pace of industrial growth, but it also provides a potentially larger market in which to sell goods and services. The question facing Germany as it integrates its East German provinces is the availability of investment capital. The countries of the former Soviet Union, now on the periphery of this newly consolidating economic giant, will serve as an additional market for European industries. It will probably be several years before the impact of the former Eastern Bloc nations on the European economic structure will be known. However, it appears likely that these three potential trading partners will have a very influential role to play in the next several decades. Interestingly, one of the first large investments made by Western European nations in the Eastern European nations has been in transportation infrastructure. Clearly, the Europeans are viewing transportation links as a key to the economic vitality that they hope to enjoy.

Japan stands in much the same position relative to the emerging nations of Asia as Germany does to the new European Community. South Korea, Taiwan, Singapore, Hong Kong, Thailand, and Malaysia are all part of this group, and Indonesia and the Philippines are now being included. China and India, though more tentative partners, function relative to this industrial concentration somewhat like Russia and the other former Soviet countries do to Europe. However, with their massive market, China and India appear to be ideal partners for the type of trade associations that will probably develop in this part of the world. It is interesting to note that Japan has been investing in this region for many years. The percentage of Japan's exports that goes to Asia is now equal to the percentage that goes to the United States, once its predominant trading partner. Because of the physical characteristics of this part of the world, however, the primary transportation interest in this economic association is waterborne and air transportation (this ignores the tremendous rail and highway potential of China). It is no accident that the largest increase in passenger air transportation in the world is expected in Asia, or that some of the most modern airports being constructed anywhere in the world are found here (e.g., Hong Kong).

The United States, Canada, and Mexico form the third major trading bloc in the world, the North American Economic Community. With the signing of the North American Free Trade Agreement (NAFTA), these three countries will, in essence, function as a single economic community. The countries of Central and South America are the western hemisphere's equivalent of the outlying countries to the trade regions identified earlier. North American manufacturing systems have been developing among these three countries for decades, and many U.S.-based industries have had manufacturing plants in Mexico for years. Canada has been the major importer and exporter of goods to the United States for more than 100 years. Given the very long borders shared by the United States with its neighbors, transportation issues will certainly rank high among the programs and challenges to be faced now that NAFTA has been signed.

Of course, many imponderables could change the trade patterns that flow out of this picture. The General Agreements on Tariffs and Trade, or GATT, is only part of the current set of unresolved issues. Although it is not clear whether NAFTA will change the existing patterns of trade, it is clear that foreign trade between the United States and other countries will continue to grow at very high rates. As a consequence, both domestic and international transportation capabilities will play an increasing role in our nation's economic affairs.

Change in Product Mix

The past two decades have seen a tremendous proliferation of both products and product lines being produced by American companies. For many goods, the consumer can buy from even a range of quality in craftsmanship. Many items, of course, are designed to work as components of, or in conjunction with, other items. As a consequence of this large increase in products, model numbers or stock keeping units (SKUs) have grown at an ever-increasing pace.

To keep companies from being swamped with unwanted inventory, automated inventory control processes have been developed in both the manufacturing and retail industries. Point-of-sale computers identify the products that customers are buying and adjust the manufacturing and distribution process accordingly. Companies also focus on ways to miniaturize the product, to improve the packaging to reduce transport cost, and in some cases to design the product to be shipped as "in-process" components, which are then completed to customer specifications only after they reach the local market.

Recently, many products have become lighter, more expensive, more carefully packaged, and, using lighter and tougher materials, more transportable. Finished goods and components account for a larger portion of the transportation budget of the country, whereas raw materials used to account for the greatest percentage.

Drive for Quality

One key to success in business is the provision of goods and services that meet a given standard of quality, which is perhaps the surest way to differentiate a product and thereby increase its demand. The drive for quality is clearly a hallmark of the 1990s: every company would like to have its goods or services recognized as products of high quality.

Quality is measured in a number of dimensions, including consistent performance, customer-sensitive design, endurance, beauty, safety and stability, and dependable prices. One reason that customers develop loyalty to a brand is that they know what they will get and approximately what price that they will pay. For retail industries, quality also implies a broad range of choices, ready availability of product, and consistent service. For service industries, and for transportation in particular, high-quality service means that equipment is available to provide service when the shipper wants to ship and it must be prepared to go where the shipper wants the product delivered. For goods transportation, the logistics system must guarantee the delivery of the shipment on time, at the consignor's location, with absolute reliability.

The link between quality and transportation reliability is a key issue that relates this transportation characteristic to effective and efficient highway systems. Congestion on the highway system or major bottlenecks as goods reach transshipment points are usually characterized by high levels of unstable traffic and unpredictable delays. It is clear that finding a way to increase the reliability of service provided by transportation systems is one of the most important objectives of future investment in the system.

Elimination of Inventory

Long thought by managers as essential to running an efficient business, inventory is now viewed as part of the production process that is best characterized as "the smaller the better." Large inventories represent an inefficient use of resources and production time. Many companies are now trying to eliminate inventory wherever they can find it: materials on order, in-process goods, defective goods, finished goods, goods trapped in the distribution system, goods in transit, and goods on store shelves in excess quantities.

Distributors face increasing pressures to be more efficient. Companies such as Wal-Mart, K-Mart, Toys-R-Us, the Gap, the Limited, Safeway, Whirlpool, and a host of other "new wave" distributors of consumer products have organized themselves to purchase, assemble, and distribute goods very profitably. They have all learned how to reduce inventory tied up in their distribution system to an absolute minimum. Part of the secret is the use of mixing warehouses to stage the delivery of products to retail outlets. Another technique is to use the shelf space in each store as the only inventory carried and to combine low shelf inventory with frequent replenishment of only what is sold. This is facilitated by updating the inventory using computerized cash registers at the point of sale to automatically trigger selection, picking, and loading of the truck with exactly the amount of product that replenishes supply. Then, armed with the knowledge of what is selling and where, managers can adjust purchasing to fit the

marketplace. The strategy of these distribution companies is to minimize inventory at every stage in the process without sacrificing service. They view it as increasing inventory "turns," and increasing the number of inventory turns is one of the ways in which the nation's profitability can be improved.

Changes in Regional Distribution Systems

The process of expanding the retailing operation in order to realize economies of scale and to increase inventory turns has been under way for years. A major step took place as a consequence of the rise of the personal automobile. One might call it the automobile revolution. After World War II, families, mobilized by their new cars, could live in the suburbs and shop over comparatively long distances. Chain-operated supermarkets replaced single-proprietor corner grocers. With an automobile-based society, each supermarket draws from a tributary area established by convenient driving distances in an automobile (5 to 10 mi) rather than by possible walking distance from the store (less than 1 mi). Shopping malls sprang up, offering virtually the same line of products available in the city's downtown, and with less bother and expense for parking. Larger stores, drawing from a larger market area, funnel more goods through each store, increasing the turnover of merchandise, reducing inventory, and contributing to higher profits.

Society is now engaged in a second distribution revolution. This one is based on the principle of the mixing warehouse. The new model of efficient distribution establishes regional distribution centers where goods are shipped direct from the manufacturer in full truckload or carload lots to a mixing and store replenishment warehouse. Truckloads of mixed products are distributed very often from these increasingly large regional centers. Many companies are now redesigning their distribution systems to cope with the proliferation of products and the increased demand for service quality (both of which could result in an increase in the amount of inventory carried) and the need to reduce inventory (to lower the cost of inventory carrying charges).

This second distribution revolution is well under way, but it has accelerated during the last decade. The most often cited example is Wal-Mart's well-planned purchasing and distribution philosophy, designed to capitalize in every possible method of lowering inventory and increasing turns. Wal-Mart is not the only successful innovator. The new wave distribution companies described earlier all draw from the same basic strategy. One sure way to reduce inventory in the system while maintaining an adequate buffer of safety stock is to consolidate the inventory of several local warehouses into a single regional warehouse. Fluctuation in the demand of each of the outlying local warehouses is smoothed by combining several "use" streams into a single larger stream, with fluctuations that are smaller, percentage-wise, that they would be at individual local facilities. The reduction in the amount of safety stock in the system as a whole is $1/n$, where n is the number of warehouses eliminated. Consequently, replacing 25 warehouses with 1 reduces the amount of safety stock inventory to 20 percent of that required to protect the original 25 warehouses with safety stock held in each individually.

The key to making this strategy work is frequent, on-time transportation. Transport from the factory to the mixing warehouse must be just in time. If goods arrive early, they will crowd the mixing warehouse and add to inventory carrying costs. Likewise, replenishment of stocks in the store must be both frequent and timely if store buffer stocks are to be kept low. This means that store delivery by truck must be well-organized and located close enough to be able to handle emergencies. For daily deliveries of fast-moving inventories, this distance from a regional distribution center to the stores it serves should probably be less than 50 mi (see Figure 2). This distance appears to be the rule of thumb followed by food stores and other retail distributors of highly perishable products. For nonperishable goods moving more slowly, the distance from the regional distribution center can be greater. The distance that can be reached in a day of driving with return to the home base on the same driver shift is 200 to 250 mi, which will allow drivers to be domiciled at the distribution center and will not require them to "overnight" on the road. This both lowers costs and facilitates the recruitment of high-quality drivers.

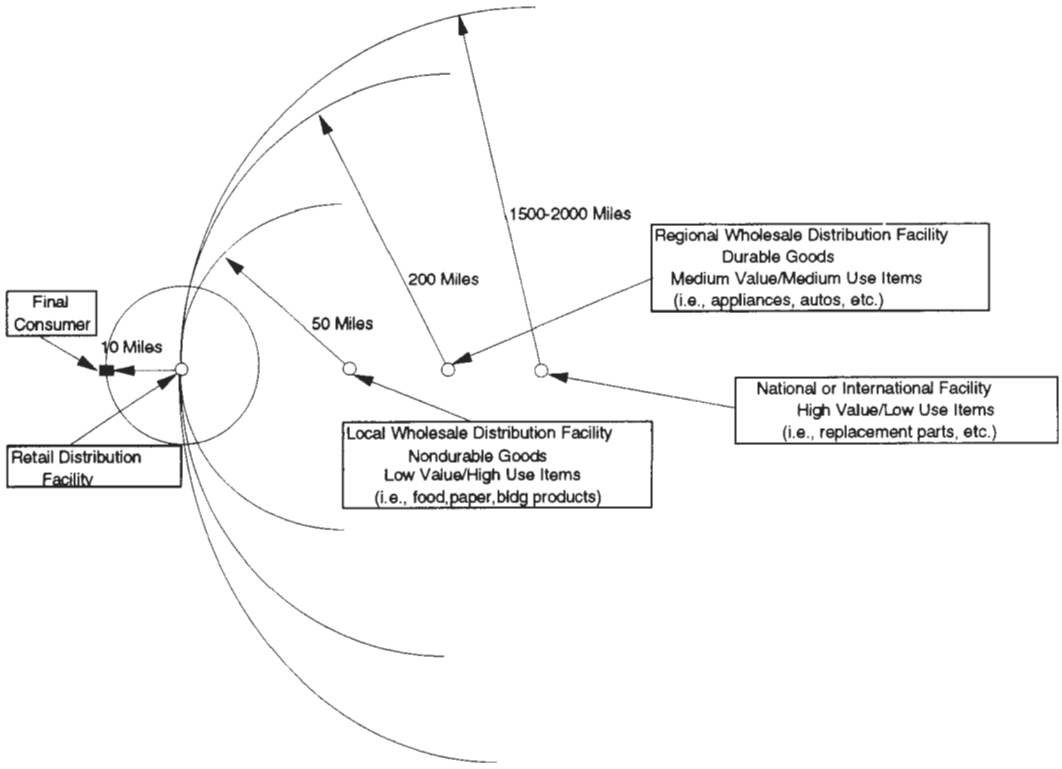

FIGURE 2 Spatial relationships between levels.

Eastern Pennsylvania, for example, is particularly well located as a distribution point for the Mid-Atlantic region. A population of 17 million resides within 100 mi of Harrisburg. A 200-mi circle will serve 44 million people (see Figure 3 and Table 1). The personal consumption expenditures of 44 million people are an astounding $515 billion/year. Food products alone account for $36.4 billion. This is 1,492 truckloads of food that must be delivered each day. For all personal consumption products delivered to this large population, 7,511 truckloads of products must be delivered each day. Major distribution centers are developing in other sections of the country: Columbus, Memphis, and Atlanta come immediately to mind. Retailers are all looking for the ideal site for locating new, larger distribution centers. These new regional distribution centers will need the central location, the road system, the vacant land, and the skilled labor force required to function as distribution facilities for the year 2000.

It appears likely, therefore, that the smaller stores and local warehouses served by strategically located mixing warehouses that have characterized the U.S. economic structure for years will continue to be replaced by more efficient retail operations as regional wholesale distribution centers. How far along the nation is in this transition is hard to say—a guess is 30 percent. If so, another 70 percent of retail operations will be forced to modernize and update their existing facilities, eliminating inefficient, small, local warehouses and replacing them with larger and more efficient operations. These distribution centers will use modern inventory control procedures, computer-directed stock picking, loading of trucks, and routing of loads to the retail stores. Computer-linked trucks will allow real-time control of shipments. Specialized transportation teams will perform the store delivery and, in some cases, install equipment.

Public-Private Responsibilities

Transportation has been a service that falls in both the public and private sectors. Over the history of the United States, however, the primary responsibility for providing this service has

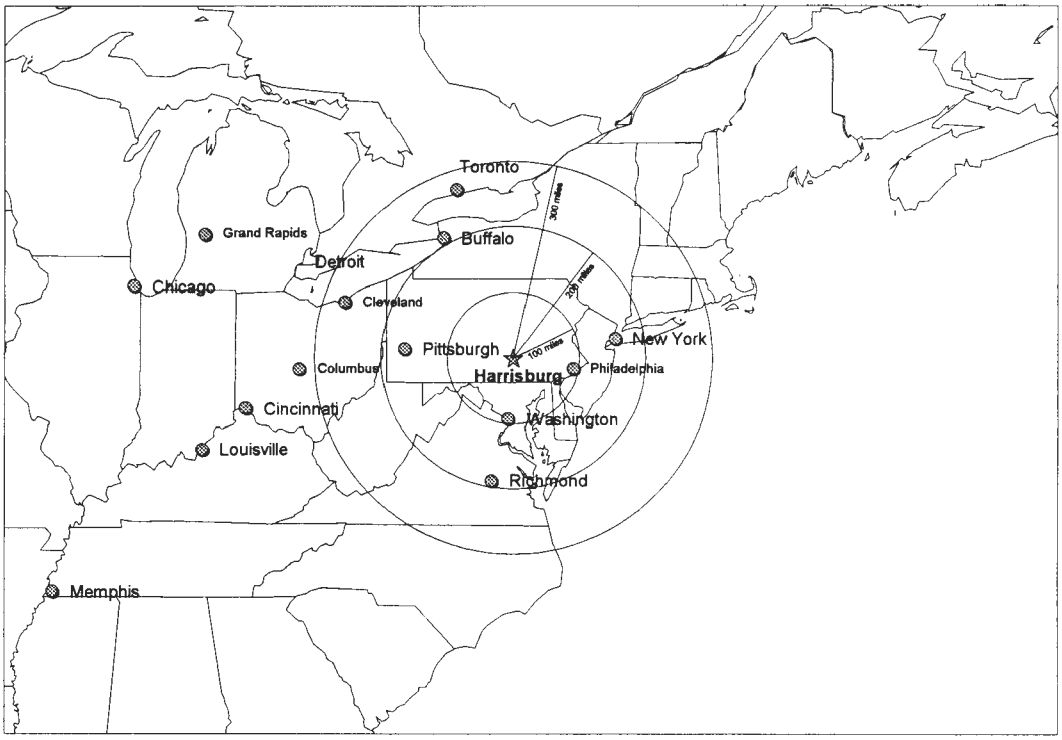

FIGURE 3 Distribution centers in Pennsylvania.

swung back and forth between sectors. Now the pendulum appears to be in the middle. ISTEA has created a new era of public-private interaction in transportation decision making and planning. At a recent TRB conference on intermodalism, participants concluded that strong public-private sector relationships among the many actors involved in transportation planning and decision making will truly benefit all those who desire an effective and efficient transportation system. A relationship does not necessarily mean that a partnership is required or, for that

TABLE 1 Markets for Pennsylvania-Based Distribution Centers (*13*)

	Radius from Harrisburg		
	100 mile	200 mile	300 mile
Population	17 mil	44 mil	66 mil
Personal Consumption	$205 bil	$515 bil	$685 bil
Food Products	$14.5 bil	$36.4 bil	$48.4 bil
Truckloads of Food/Day	595/day	1492/day	1983/day
Apparel	$4.8 bil	$12.2 bil	$16.2 bil
Truckloads of Apparel/Day	40/day	100/day	133/day
Paper products	$.9 bil	$2.2 bil	$3 bil
Truckloads of Paper Products	73/day	184/day	244/day
Motor Vehicles	$7.9 bil	$19.7 bil	$26.2 bil
Motor Vehicles by Truck	75	188	249
Truckloads All Products/day	2997/day	7511/day	9985/day

matter, desired. A partnership should not begin until an agreement on a clearly defined and understandable set of values and commitments can be consummated. Thus, to develop partnerships, there will be an initial period that will require an investment of time in communication and education to decide whether a partnership makes sense. On the basis of this understanding of the process, however, the conference concluded that there would be benefits associated with intermodal partnerships.

The rules of the game have been changing dramatically over the past several years. Regulatory policies are being relaxed for most modes. The use of private-sector toll roads is growing. Given the importance of efficient transportation infrastructure to the well-being of the nation, both the public and private sectors have a stake in making sure that such infrastructure is provided.

Issue 1

Should the United States have as a fundamental goal of its national transportation policy the provision of a national transportation infrastructure that will achieve the economical movement of freight through the United States?

Options

- The federally aided transportation infrastructure in the United States is planned and designed to achieve several policy objectives, including enhancing mobility while preserving environmental quality. This diversity of focus of national transportation policy should continue with the efficiency of freight movement included as one of many goals for transportation improvements.
- The "I" in ISTEA stands for "intermodal." This benchmark legislation for the first time acknowledges the important role that freight movement has in the economic well-being of the nation. The United States should establish a policy toward transportation investments that will enhance the efficiency of freight movements.
- Given the world market in which the U.S. economy is now competing, the United States should provide targeted investments for those facilities (e.g., ports and airports) that serve as critical links to the world market.

Recommendations

The movement of freight throughout the nation is a critical factor today, and will become even more important, in defining the ability of the United States to compete internationally. It is probably too expensive to provide a separate freight delivery system, yet both manufacturing and distribution/retail companies cannot continue to realize economies associated with new approaches to logistics without some guarantee of service reliability incorporated into the transportation system. The United States should aggressively pursue a national transportation policy that has as one major focus the efficient movement of freight and goods.

Implications for Transportation System Requirements

The previous paragraphs provided some characteristics of the changing production process and world economic order that will affect how the United States will survive economically. These can be described as changes in

- Production process and desired product characteristics,
- Locations of economic activities,
- Structure of industrial sector,

- Competitive nature of a world market, and
- Importance of service sector.

Role of National Highway System

As has been suggested, the ability of the transportation system to handle the movement of people and goods in an efficient and effective manner is critical for the United States to enhance domestic economic vitality and for U.S. industries to prosper in the future world economic order. There is strong evidence that the NHS in particular is a critical component of national economic productivity. In a recent report, FHWA provided the following conclusions regarding the relationship between highway investment and productivity:

> While the magnitude of the relationship between highway investment and economic productivity may have been overstated by some economists, national production function estimates do signify the existence of this linkage. Studies suggest that a decline in public capital is responsible for almost half the decline in U.S. productivity. . . . Arguments that public capital does not contribute to the productivity decline are not realistic. The public contribution to provide production of goods and services has been largely and conveniently ignored because economic analysis techniques are oriented to private enterprise. . . .
>
> The majority of state-level studies indicate that public capital has a small, positive effect on private output and productivity, and that the decline in public capital is a factor in the decline in productivity. . . . When investment in highways is identified as a separate component of public capital, it often yields the strongest effect on productivity of the public capital variables (*1*).

In addition, the National Transportation Strategic Planning Study concluded in 1990 that the industries likely to be expanding over the next decades will be extensive users of transportation and that speed and reliability of service will continue to be major determinants of the demand for transportation services. The report states that an effective transportation system is critical to the continued economic health of the nation (*2*).

Clearly, the changing industrial process and world economic order will have a profound impact on transportation, just as transportation will have a profound impact on the ability of the United States to compete in the changing world. From a market perspective the demand for transportation will be for speed, reliability, security, and flexibility (i.e., ability to change rapidly to changing technologies and market trends). This means that highway investments aimed at enhancing economic productivity and competitiveness should have several characteristics that will help meet economic competitiveness requirements.

Perhaps the most important characteristic is that the NHS needs to be just that, a *national system* of highways that is designed and operated to allow for efficient movement of goods and people. The system needs to connect major economic activity centers and, in the context of a world market, provide efficient connections to locations of import and export activities. The system should be designed to allow for the safe movement of goods (C. M. Walton's presentation "Highways for Efficient and Safe Goods Distribution"), efficient movement (see paper by Zogby in this Proceedings), and provide reliable and quality performance to those who use it. Of course, the Interstate highway system provides the backbone of such a system, and the ISTEA-required designation of the NHS takes the next step. However, as will be discussed, certain characteristics of such a system designation, and ways in which investment priorities are set, should be considered if the system is truly to serve as a foundation for the economic well-being of the nation.

The importance of such a system of "economic" highways has not gone unnoticed by others. In Europe, for example, the Trans-European North-South Motorway System is under development; it will consist of 10 000 km of roadway connecting Poland to Italy and Greece. Other corridors from Sweden to Italy and from France to Morocco are being examined. The European nations have agreed to develop an "E-Road" system of Interstate-type highways that are designed to have consistent geometric and operating standards that will provide for fast and

reliable cross-continental travel. In addition, several more trailer-on-flatcar tunnels through the Alps are being planned to expedite freight movement along the north-south European axis.

The Mexican government is especially interested in the improvements of highway links to the United States. Only 8.5 percent of the primary roads in Mexico are more than two lanes, and in most cases even these are far inferior in geometry and safety design to U.S. Interstates. And severe congestion and safety problems exist at border points. The Canadian national government, with the cooperation of the provincial governments, is planning to establish designated highways for transnational movement of goods and people.

Importance of NHS to Success of NAFTA

Perhaps the most important recent economic and trade opportunity that will affect the U.S. market, and thus the transportation system, is NAFTA. The impact of NAFTA on the United States, Canada, and Mexico could be significant. For example, roughly 65 percent of all U.S. industrial exports to Mexico will be eligible for duty-free treatment within 5 years after enactment. Within 3 years, all parties may make cross-border deliveries, and within 6 years, trucks will have access to all of the United States and Mexico.

However, as noted by the California Department of Transportation in a discussion paper on NAFTA, "the benefits of NAFTA will be only as good as the transportation facilities available and the efficiency of border clearances provided by the three countries" (*3*). For the most part, NAFTA leaves infrastructure decisions to each nation and to each border state. This will be a particularly important issue for the border state highway systems in that the preferred form of goods movement across both borders in the foreseeable future will be by truck.

Issue 2

Given the importance of a NHS to the economy of the United States and its trading partners in NAFTA, how can we be assured that the designed system achieves objectives associated with the movement of freight throughout the United States?

Options

- The federally mandated NHS should be established with national objectives in mind, similar to the interstate transportation and defense objectives that were established for the Interstate highway program. The movement of freight should be one of the most important national objectives in the definition of a NHS.
- Travel corridors serving likely NAFTA import and export routes should receive primary emphasis in early NHS designation, with special investments targeted to these corridors.
- The approach currently being followed for NHS designation, primary responsibility resting with the states, should continue, with some guidance provided for consideration of freight movement.

Recommendations

All of the options presented must be adopted, at least in part. An NHS must in fact be an international system, connecting the producing and consuming areas of each region and the major interchange points in the transportation system across the entire continent. The coverage should be seamless, without discontinuities caused by differences in standards and designation of facilities. The system must pay particular attention to freight moving at the national, international, and regional levels. It must also embrace policies that will promote smooth functioning of the freight system at the local level in concert with local passenger movement. All of this must be done within the constraints that exist on funding, sovereignty, and operating responsibilities. Thus the designation of the system must be coordinated between governments,

with the federal government taking a leadership position, providing guidance in system designation where national concerns are paramount.

Interstate transportation and access to the world market are clearly to be considered national concerns. What is needed are reliable funding sources and quantitative measures for priority ranking the flow of investment and operating capital and directing it into the parts of the system most important to the country's aggregate economic performance. Setting out a quantitative process for designating priorities is a larger job than can be undertaken in this paper, but it is fundamental to the success of the planning process.

ISTEA Requirements That Affect Transportation and Economic Considerations

In the United States, ISTEA has provided an impetus to examining the nation's highway system in the light of concerns similar to those just discussed. First and foremost, ISTEA has placed great emphasis on the true intermodal nature of transportation by calling for the development of a National Intermodal Transportation System. The system is to move people and goods efficiently and achieve broad national goals; it is expected to be the centerpiece of the economic survival of the United States in the 21st century. States and metropolitan planning organizations (MPOs) are directed to prepare plans and investment programs that meet a variety of requirements. For MPOs, ISTEA provided 15 factors to be considered in the development of these plans and programs, including the consideration of improved border crossings and access to ports, airports, intermodal transportation facilities, and major freight distribution routes, and methods to enhance the efficient movement of freight. Similar requirements exist for state departments of transportation, which must consider "methods to enhance the efficient movement of commercial vehicles." In addition, the MPOs and state departments of transportation are required to develop management systems that will provide important information on the transportation investment decisions made across the nation. In particular, the congestion management and intermodal management systems will be directly related to the concerns of freight movement. ISTEA is then a strong foundation for establishing a planning and programming process that actively considers efficient movement of freight within metropolitan areas and across states.

Designation of NHS

Perhaps the most important requirement of ISTEA as it relates to this discussion was the requirement for Congressional approval in 1995 for the NHS, a system of 155,000+ mi of principal arteries serving major cities, border crossings, ports, airports, and other transportation facilities. The NHS funding provided by Congress can be used only for the construction and operational improvements of NHS roads, for adjacent facilities that improve service on the NHS roads themselves, and for some other assorted activities. Road access to ports, airports, and intermodal terminals is eligible for these funds and is considered by many as a Congressional priority. To a large extent, the designation of the NHS is the activity of the state departments of transportation, with guidance from FHWA.

This process has not been without some controversy. Some states such as California have argued that specific criteria such as access roads to federal lands (e.g., parks, military bases), access to ports and airports, and Interstate road designation should be used as criteria for designating the NHS. This argument is based primarily on the desire to have consistent designations from one state to another, so that similar types of facilities are designated in all of the states. The counterapproach to the criteria-driven process is to allow the states to designate the roads for the NHS as they see them fitting into their own states' road network and providing for federal review after the proposed plans are submitted.

It is not the purpose of this paper to take a side in these different approaches. The NHS that would be designated with either approach would be very familiar and, certainly from the

perspective of freight movement, most likely identical. However, the intent of ISTEA seems clear. The NHS should enhance intermodal movement of goods and people, and national economic concerns should be considered in NHS investment. Therefore, the development of the NHS and the subsequent review should be linked directly to the economic opportunities provided by this system. Several criteria for such an influence in NHS designation include, but are not limited to, the following:

- Access points to ports;
- Access points to airports;
- Access points to border crossings;
- Access points to intermodal terminals;
- Roads linking major economic regions to export transshipment locations;
- Interstate-type roads with high-speed, high-capacity characteristics;
- Bypasses of major congestion locations;
- Access links to major warehousing locations; and
- Roads that can handle certain sizes of trucks.

Setting of Performance Levels on System

Of greater importance, however, than designating these elements of the NHS is setting the performance levels. One could argue that ISTEA has institutionalized a new approach to planning, one based primarily on establishing system performance targets or goals. For example, an FHWA-sponsored working group that gathered in 1991 to discuss the concept of a congestion management system developed the following definition of such a system: "A congestion management system is the continuous activity of considering and implementing actions that enhance mobility and reduce congestion on designated systems or in targeted areas, appropriate to the magnitude and scope of desired system performance" (*4*).

Two aspects of this definition relate nicely to the topic of this proceedings. First, targeted systems or areas are those corridors and facilities that will be important to a national transportation system. State and local officials can also identify subareas where severe congestion levels occur that should be targeted for special attention. Second, performance measures, defined by state and local officials, should be the basis for determining progress in achieving performance objectives. These performance measures should measure the extent, severity, and duration of congestion and the reliability of system performance. Although most participants at the FHWA workshop did not believe that national performance standards should be set for specific types of facilities, such as Interstate highways, others thought that such standards were the only way to preserve the integrity of nationally important facilities. Generally, it was believed that the performance measures should be considered targets, with perhaps some "desirable" minimum targets for certain facilities.

Another meeting, this time focused on intermodal transportation issues, again raised the issue of performance-based planning (*6*). The basic elements of an intermodal management system were recommended to include

- Inventory of modal and intermodal elements including institutions, markets, operations, and physical plants;
- Identification of an intermodal system that becomes the focus of the intermodal management system;
- Use of performance measures that will allow some sense of how the system is doing over time and where problems exist;
- Identification of strategies and actions that will improve intermodal transportation efficiency and effectiveness, including non-investment options such as pricing, regulatory changes, and so forth;
- Analysis and evaluation of these strategies and actions from the perspective of intermodal concerns (e.g., economic value to system users, cost, improvement to system interconnectivity);

- Establishing priorities among strategies and actions within the context of the overall planning effort; and
- Mechanisms for including users and providers in this process (e.g., advisory groups).

Once again, the concept of system performance was an important characteristic of the planning process that informed investment decisions. Because the focus of the intermodal management system included both freight and passenger transportation, the recommended performance measures were much broader than those discussed for the congestion management system. Several system performance measures were identified:

- Level of service,
- Trip time,
- Quality of travel,
- Cost of travel,
- Safety,
- Reliability,
- Convenience,
- Amount of capacity,
- Energy use or efficiency,
- Environmental impact,
- Flexibility in accommodating new intermodal services, and
- Opportunity for expansion of intermodal capabilities.

Establishing Minimum Levels of Performance

If the NHS is to provide the type of safe, reliable, and efficient service required to compete in a world market, it seems reasonable to expect that this system should achieve some minimum level of performance. This means that roads of economic significance should be expected to achieve certain target levels, similar to the existing national goal of achieving air quality standards in nonattainment areas. For those areas not able to reach these standards, the states and metropolitan areas need to show a program of action that will lead to eventual attainment. So too for national "economic" highways, it would be proposed that such designated roads must meet certain levels of performance and that, if the levels were not already attained, states and MPOs would need to show the steps necessary to achieve them.

The model for this approach can already be found in many states. In Pennsylvania, for example, the Pennsylvania Department of Transportation many years ago developed a commercial and economic highway network that was designed to handle the major truck improvements (e.g., bridge reconstruction) that were fed into the investment priority–setting process for the state. In this way, the road system considered most important for the economic vitality of the state received priority treatment. This is similar to what is being proposed here. This process could also be easily implemented through the management systems now being developed by every state and MPO in the nation.

With regard to international trade routes and systems, the performance and geometric criteria needed to enhance the efficiency of trade transportation could be incorporated into the decision-making process. Of course, the first step in this process is designating these trade routes. This step is already under way by Congress and FHWA. FHWA is currently undertaking an International Trade Corridor and Facilities Study that will include a comprehensive network analysis; the identification of international trade corridors; the identification of border crossings, major ports, major highways, and other transportation modes within the corridor; the coordination and identification of trade corridors and facilities on both sides of borders; and an assessment of the potential contributions of advanced technology applications. A report to Congress is expected in June 1993 on these issues. This much-needed effort will go a long way toward taking the initial steps that are required to relate road networks to national economic competitiveness. However, these steps provide no insight into how transportation investments

should be ranked to provide for acceptable level of service in these corridors as suggested. This is the next important step in the process of relating the future road network to national economic competitiveness.

The NHS is used for moving both people and goods. And as has been pointed out in other papers in this proceedings, the different types of vehicles using a highway result in certain design requirements and thus varying costs. The national productivity enhancements from highway investment mentioned earlier and, in particular, the highway investment needed to respond to non-facility productivity improvements coming from the freight industry (e.g., truck size), require that trade-offs be made. These trade-offs not only occur between what can be achieved by the motor carrier industry if certain investments are made by public agencies, but also relate to longer-term trade-offs in public policy objectives associated with environmental quality and energy consumption.

Issue 3

Can the NHS be designated and performance measures established to ensure that it functions as required?

Options

- A broad set of criteria for designating the system and establishing performance measures that will apply across the entire system should be developed.
- Economic criteria for designating the system and establishing performance measures that vary according to the economics of the situation should also be developed.
- The federal government should set minimum levels of performance for NHS routes that are considered highways of economic significance.

Recommendations

The criteria used to designate the NHS and to establish performance measures must have some consistency if they are to produce the proper effect. At the same time, they should have an underlying economic rationale. It is not necessary, for example, to maintain the high operational standards in rural areas that are necessary in heavily congested urban areas. Minimum standards of operating performance should be established for highways on the basis of their economic significance. The federal government should either provide strong guidance on such minimum standards or require that they be maintained.

Trade-Offs Between Motor Carrier Productivity and System Capacity

Shipper Requirements for More Productive Operations

Given that transportation is considered nothing more than a part of the production process, shippers are interested in the most cost efficient transportation of the product and of the elements that go into producing the product. This is always a trade-off between price, quality, and service capacity. The successful supplier is one that can provide the product to the buyer in the quantities needed, at the location specified, in the most cost effective package overall when measured in total costs to the receiver (including ordering, transport, storage, capital carrying, stockout, and emergency shipment costs, to name only a few).

In transportation, this trade-off has become sharper as shippers have discovered the crucial importance of reducing inventory while increasingly designing their entire distribution systems to capitalize on truckload or carload purchases of a particular product from a single supplier to regional mixing centers. This means that reduced transportation costs can occur if greater

volume is transported from one distribution location to another. Once there, goods are then delivered to stores on a very frequent basis. This process as a whole depends on reliable supply direct from the original source and frequent, highly reliable transportation service at every point in the distribution process.

An excellent example of how shippers' demands for reliable and secure transportation resulted in a revolution in freight transport is the container. From a simple, converted tanker, carrying 58 trailer vans in 1956 to the now enormous container trade throughout the world, the reaction of shippers to this innovative form of freight transportation has revolutionized goods transport. Such service has caused realignment and regrouping of carriers on major trade routes, has generated more competitive vessel design, has led to innovative ocean vessel operations, and most important to the shipper has produced many new routing and pricing alternatives (*6*).

Carrier Responses to Shipper Needs

Carriers have chosen to respond to shipper needs with a variety of new services. The most visible is just-in-time delivery, which delivers the quantity of inputs required for the day's production at exactly the moment it is needed. But this is only one example of how carriers have been responding to market demands. Shippers need to know that equipment is available to meet their frequently variable needs, and carriers have entered strategic alliances with shippers to ensure the flexibility that they need in their operations. Indeed, some carriers have entered alliances with what had been considered their traditional competitors to guarantee the existence of sufficient capacity. More and more shippers are selecting a set of "core" carriers to provide all of their transportation needs instead of dealing with hundreds of carriers on a day-to-day basis. Creative pricing, including multiple independent factor rates and long-term contracts, are also a part of this carrier response to rapidly changing shipper needs.

Truckers have increased their productivity through the use of more and larger trailers. The Surface Transportation Efficiency Act of 1982 (STAA 92) prohibited state restrictions on the use of less than 48-ft, 102-in. semitrailers and 28-ft doubles in all 50 states. This action allowed a 13 percent increase in carrying capacity for those products that could use the higher cube semitrailers. For LTL carriers that switched to doubles, it was a 33 percent increase in productivity over the old 45-ft trailers that had been the standard. These productivity increases fueled the desire of truckers to use even larger trailers. The STAA legislation did not preclude the use of longer semitrailers, and the 48-ft standard has now almost been replaced by the 53-ft trailer, and the interior height and width of the equipment has been augmented by the use of low radial tires and improved plate trailer design. Truckload carriers wanted turnpike doubles to be allowed on the Interstate system, whereas LTL carriers preferred to be allowed to use triple 28s. These longer combination vehicles (LCVs) were the subject of intense debate in the legislative maneuvering before the passage of ISTEA, but their use was deferred until after Congress could receive a report concerning their impacts on the highway system.

At the same time that truckers were achieving efficiency gains by using larger equipment, railroads were busy doing the same. Since 1983 railroads have developed double-stack intermodal service, which carries two containers for less than the previous cost of one, and what appear to be dramatically more efficient RoadRailers, which provide for the movement of highway trailers without the cost and time delays or the loading and unloading involved in trailer- and container-on-flatcar operations. Double-stack service, which was motivated by the need to deliver maritime containers traveling in international trade to inland destinations, has now spread to the carriage of domestic containers. Double-stack containers have been designed with the same carrying capacity as 53-ft-high cube highway trailers, and truckload carriers have indicated that they are interested in entering long-term arrangements with the railroads to provide this service. Maritime carriers—which pioneered containerization and the science of loading, unloading, consolidating containers into loads, and deconsolidating them for sorting and delivery—are now addressing the full-scale automation of this process.

Obstacles to Carrier Response to Shipper Needs

Many barriers are associated with effective carrier response to market demands, from institutional constraints to geometric design of existing facilities. This paper will focus on the highway system, assuming that the important constraints not related to the highway system will be covered by the other papers in the proceedings.

As noted, the major shipper needs relate to fast, reliable, and flexible transportation. This means that the highway component of the transportation system must provide this type of service. The principal barrier to the continued growth and development of America's transportation system is the mounting congestion in the operation of the system. Urban highway congestion is perhaps the most important source of inefficiency in the current goods movement system, and it is growing in a way that threatens the performance of the transportation system as a whole. (The congestion in New York City and its surroundings, for example, has led long-haul truckload trucks to impose a surcharge of $200/load on movements into or out of New York City and Long Island.) Pickup and delivery of goods is handled almost exclusively by truck. Trucks perform consolidation and deconsolidation for the rest of the system. Whether the move will travel by air, water, or rail, the pickup and delivery segment of the trip is by truck, the exception being bulk liquids such as those handled by pipelines or bulk dry goods typically handled by rail or barge. Ways must be found to improve the pickup and delivery function performed by trucking without getting tangled in the daily commuting patterns of the population; suggestions include truck-only roadways, urban bypasses, and integrated multimodal terminals.

Trade-Offs Between Vehicle Configuration and Cost of Highway System

One of the possible productivity improvements in the existing delivery system is to increase the carrying capacity of individual vehicles. Over time this nation has allowed increases in truck size, and the pressure to continue this growth continues. LCVs are advocated by some as the answer to increasing the nation's productivity. Others see them as a threat to safety and as a degradation of the driving environment on our highways. Engineers view them as being detrimental to maintaining the structural integrity of the highway network. Those responsible for highway finance and economics see these larger vehicles as a tremendous cost burden because of the changed design standards of the system.

The types of impacts for different vehicle configurations depend heavily on the context within which the vehicles are permitted. For purposes of this paper, a distinction will be made between impacts per truck unit that are associated with the individual use of a vehicle and the aggregate impacts that are really a function of the systemwide context of such use. At the individual unit level, several studies have examined the probable impacts of larger trucks on the condition and performance of the system. A study of the impacts of LCVs on pavement costs performed by the Urban Institute concluded that pavement damage would be reduced if LCVs were allowed on a nationwide network (*7*). This is possible because the heavier load is spread over a longer vehicle with more axles, allowing the same tonnage to move in fewer vehicles. Axle loadings remain limited by Bridge Formula B, however, so that the cost savings in reduced pavement deterioration are solely the consequence of having fewer trucks run over the surface. The study estimated that if LCVs were allowed on a national basis, the pavement savings could range from $15 million to $65 million depending on the amount of diversion from conventional vehicles to LCVs. Significant amounts of freight were estimated to shift.

Studies of Turner trucks published by TRB found pavement cost savings for combination trucks using twin trailers (34 ft each) that are only slightly longer than those currently in operation (*8*). The study recommended, however, that a maximum of 15,000 lb be allowed on a single axle and 25,000 lb on a tandem axle, compared with the current federal limits of 20,000 and 34,000 lb, respectively.

The cost of replacing deficient bridges on the Interstate system and major primary highways has been estimated in at least three recent studies. These are the Turner truck study (*7*),

the Urban Institute study (*8*), and the University of Texas study (*9*). Results of the studies differ substantially. The Turner truck Study concluded that increased bridge costs associated with authorizing the use of vehicles that exceed the current 80,000-lb gross weight capt but that are less damaging than triples or turnpike doubles, would have replacement costs of $6.3 billion. The Urban Institute study estimates increased bridge costs of $429 million/year. This translates into a discounted present value of about $6 billion at an interest rate of 7 percent and an unlimited life. As was pointed out by this study, every bridge on the Interstate and major rural primary systems carries higher weights than proposed for LCVs every day under current special permit provisions. State transportation agencies schedule bridge replacements every year; many are scheduled as soon as the money becomes available. Therefore, this study concluded that the annual bridge costs associated with LCV use are not insurmountable.

The University of Texas study used a somewhat different methodology, employing the inventory rating of each bridge, a safer limit (55 percent allowable stress) than the operating rating (75 percent allowable stress) used in the Turner and Urban Institute studies. The result is a replacement cost of $12.5 billion. In addition, the Texas study points out that the cost of travel delay, additional cost of fuel, and the like during reconstruction and replacement of the rural bridges amounts to another $8.8 billion. If these replacements are extended into the urban Interstate and primary highways, the total is even higher.

The difference in the costs estimated by each of these studies results largely from the assumptions underlying each study. The Turner truck study used lower axle limits and a smaller vehicle than the other studies; the Urban Institute and University of Texas studies based their findings on different engineering safety factors and assumed different sets of implementation costs. One might view them as the range of possible costs given the uncertainty in the system. Both have some validity.

This brief discussion shows some of the key issues that need to be discussed when developing a national system of economic highways. Unfortunately, very few studies have been undertaken that provide both the scope to address these very complex issues and the level of detail required to resolve them successfully. The productivity gains to the nation of implementing an LCV system and the costs that will be incurred for designating such a system of highways and making it safe for operation have not yet been adequately addressed. Both the General Accounting Office and FHWA are conducting studies in the context of the NHS designation. It is hoped that these studies will examine the trade-offs of investment with enhanced economic competitiveness.

Issue 4

How should the United States invest in transportation so that the overall productivity of the economic and transportation systems is enhanced?

Options

- To ensure that the highway system remains a strong asset to the United States economy, it should be designed and operated as a stand-alone system.
- A new form of multimodal and intermodal planning and policy analysis must be adopted in all transportation investment decisions to help select the most efficient and effective transportation investments regardless of mode.
- With limited resources, the best approach is to center highway investment on a stand-alone system but focus intermodal planning and investment decision making at those elements in the transportation system that are the transfer or terminal points.

Recommendations

The state and regional planning process must recognize that the transportation system is just that, a system, consisting of many different elements and providing services to many different

users. Innovation in freight movement requires that highway investment be examined from a more holistic perspective. The rise of containerization, for example, makes it possible to substitute rail capacity for intercity highway capacity in many of the nation's long-haul freight movements. LCVs and their impact on the functioning of the entire transportation system must be considered explicitly. At the same time, operational improvements (which might mean capacity expansion) are needed in many urban areas so that freight movement can occur reliably. First and foremost, the planners and operators of the nation's highway systems should understand the importance of freight movement to their regions and states and consider the consequences to their economies if transportation system performance deteriorates to a level at which they are no longer competitive.

Trade-Offs Between Heavy Trucks and Environmental and Energy Concerns

Highway Capacity and Congestion

The operating characteristics of larger trucks can have a sizable impact on the flow of traffic when these vehicles are introduced into the traffic stream. Some of these impacts include speed, highway capacity and level of service, passing, splash and spray, aerodynamic buffeting, merging and lane changing, and off-freeway operation. It should be noted that safety engineers and finance experts debate the exact nature of these effects. In particular, the implications of these impacts need to be weighed against the positive benefits that might accrue from enhanced productivity. Each is examined briefly in this paper.

Because of its higher gross weight and lower horsepower per unit of weight, an LCV typically has lower acceleration and slower speed on grades than conventional vehicles. Both features could be improved by adding higher horsepower if it is sufficient to achieve maximum allowable speeds on level roadways, albeit at the expense of acceleration.

Passing or being passed by an LCV is what motorists appear to dislike the most about longer vehicles. An automobile traveling 5 mph faster than an LCV requires 494 additional ft to pass a 110-ft-long LCV than is required to pass a 65-ft conventional tractor semitrailer. This is only 6.12 sec, but on a two-lane highway the exposure to a head-on collision with oncoming traffic makes it a nerve-racking experience.

The problems of passing are even greater during inclement weather because of splash and spray. Splash and spray are generated when a vehicle's tires throw drops of water onto the underside of the vehicle where they break up into smaller particles that then escape from the rear of the vehicle as spray or mist.

Merging and lane changing will be more difficult with LCVs than with conventional vehicles. A number of the factors mentioned earlier contribute to the difficulty. These include the slower acceleration, reduced handling ability, need for a longer space in which to perform the maneuver, and the difficulty in passing.

Finally, if larger trucks are authorized for use on a nationwide network that includes all or most of the Interstate system, there will be a diversion of traffic from other means of transport. Some rail movement will be diverted. Much of the long-haul truck traffic will be diverted from semitrailers and twins to these larger vehicles.

Energy and Air Quality Issues

Understanding the energy and air quality impacts of heavy trucks is complicated by the wide variety of combinations of trucks and rail services that can be provided. Piggyback service, for example, provides benefits in both categories for longer haul trips.

For long-haul movements, rail is more energy-efficient and causes less air pollution. Our figures show that fuel use per ton mile by rail is only 45 percent that by truck; however, this figure needs to be reduced by the circuitry that is typical of rail and by the inefficiencies

experienced by rail in urban pickup and delivery (*10*). Consequently, diversion from rail to truck would appear to use more energy and result in more pollution. However, diversion from semitrailer truck to larger trucks reduces fuel use. Efficient carriers using larger trucks would use only 57 percent of the fuel previously required to transport the same freight by a conventional tractor-semitrailer (*11*). There could be a net savings in fuel use depending on the diversion results. Because effluent from the burning of fuel is roughly proportional to the amount of fuel used, the air pollution impacts of LCVs will probably parallel those of fuel use.

It should be noted that several state transportation agencies have been working with trucking associations to develop guidelines for truck operations that go toward alleviating some of these issues. For example, some western states have developed a *Guide for Uniform Laws and Regulations Governing Truck Size and Weights Among WASHTO States* (*12*), which has seen some success at dealing with these issues.

Issue 5

Are the investment requirements occasioned by larger trucks worth the price?

Options

- LCV triples could be allowed to use a designated system of highways, but not turnpike doubles.
- Both triples and big doubles could use a designated system of highways.
- LCVs could be prohibited except where they are already allowed by grandfather rights.

Recommendations

The full "price" to the economy and the rest of the nation's transport system for allowing LCVs to use a designated system of highway is not yet known. With improved safety precautions, such as antilock brakes, double drawbar dollies, and rigorous operating standards, there is little reason to forbid triples on a designated system of highways that avoid urban areas. The price looks like it will be small.

By contrast, turnpike doubles are hard to accommodate on the existing Interstate network without substantial rebuilding of interchanges to accommodate their large turning radii and the construction of marshaling yards for consolidating and deconsolidating the trailers so that they will not have to travel on regular roads and streets. The funds that would need to be spent on such accommodations might be better spent on operational improvements to urban highway systems. Bypasses and truck-only roads should be considered to facilitate the movement of freight in urban areas.

Conclusions

This paper has examined the changing characteristics of the world market and the subsequent impacts on the U.S. transportation system. There is little question that the market forces of the new economic order will force major changes in the way freight moves in this country. These changes will be especially dramatic in the motor carrier industry. ISTEA provides some unique opportunities for dealing with these new challenges. The requirements for a nationally designated highway system and for states and MPOs to consider freight movements in their planning as well suggests that the national freight system should be linked to the types of highway investment strategies that will ensure a safe, reliable, and stable transportation service. There is a need to have consistent performance measures across the nation to allow this designated highway system to function as it is supposed to. In addition, the federal government in concert with state governments should target international trade corridors that are considered strategic transportation assets to the nation's economy and provide greater priorities for

investments in these corridors. Finally, the link between our nation's economic productivity and the role of freight movement requires greater scrutiny.

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New Approach to Financing Surface Transportation

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This paper reviews the status of financing surface transportation in the United States and outlines a proposed "new approach" to financing surface transportation by establishing a "new contract" between transportation agencies and their customers, which includes continued updates of agreements on objectives and investment levels. The new approach is identified not only because of financing concerns, but because of concerns about which relationships between transportation agencies and their customers will lead to the best services for the customers. Revenue sources will be chosen to be consistent with the new contract, as well as to meet traditional public financing criteria for adequate, simple, equitable, and efficient revenue sources that will perform well under future contingencies. Implications for the motor carrier industry are identified.

If structured in an internally consistent manner, the proposed new approach could provide significant improvements from the point of view of the motor carrier industry. However, as with any overall change in relationships, there is also the threat that new arrangements between agencies and their customers might be defined in a manner that leaves the industry worse off than it might have been.

The review of current issues in financing surface transportation and the new approach have significant implications for the motor carrier industry, on both positive and negative fronts. Because the motor carrier industry is but one (albeit a major) element of the use and finance of surface transportation, all decisions on surface transportation finance cannot depend solely on their impacts to the industry. Decisions about surface transportation finance must take account of overall issues affecting the role of surface transportation in the society.

A new approach must take account of threats and challenges such as environmental issues, international competitiveness, energy independence, infrastructure deterioration, and the tax revolt. It must take advantage of potential intelligent vehicle-highway systems (IVHS) and other technological advances, potential institutional innovations, and management systems mandated by the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). It must provide agencies with the means to convince their customers that user or other fees will return substantial dividends.

Until recent times, the taxation of motor fuels had been a reliable, economical, and comparatively popular method. The federal government and most state governments deposit motor fuel revenues in dedicated accounts, embracing a user-fee approach to transportation improvements and producing a reliable flow of funds that facilitated long-range planning

and programming. Now, a number of factors are reducing the effectiveness of motor fuel taxes as the primary financing mechanism for improvements in highways and other surface transportation.

There is also increased interest in technological solutions (such as IVHS) and other measures (such as pricing) to reduce the growth of congestion and fuel consumption. The technologies also offer opportunities to collect fees in ways that provide for greater equity among vehicle classes and to increase the efficiency of the transportation system by allowing variations in charges by time of day or level of congestion.

The merging of these forces results in the need to examine whether a new approach to making funding decisions or new types of funding sources for surface transportation can provide a revenue stream that is more adequate, equitable, stable, and reliable—regardless of how the future takes shape.

Summary of Current Revenue Issues

Is the System Broken?

The current and potential future deterioration of the "buying power" of existing motor fuel taxes over time has lead some key transportation leaders to conclude that if the system is not broken already, it will be soon. Major difficulties include the following:

- Revenues will fail to keep pace with inflation because fuel tax rates are fixed per gallon and are not indexed to the rate of inflation in the costs of the programs that the revenues must fund.
- Indexing of fuel taxes to the price of fuel can provide a roller coaster effect, with the revenues increasing or decreasing on the basis of factors well outside the control of transportation agencies. Even though the situation may seem positive if revenues are increasing, the problems of decreasing revenues with decreasing prices are great enough to make this type of indexing unattractive.
- Fuel efficiency increases will reduce the revenue collected per mile of travel and may result in reduced total revenues if changes in fuel efficiency more than offset the impacts of changes in vehicle miles of travel (VMT).
- Alternative fuels can complicate the revenue-raising efforts of all levels of governments by requiring additional collection and enforcement efforts, if such fuels are to be taxed.
- Legislatures have continued to attack their general fund deficits by diverting highway user fees to their general funds or by making highway agencies responsible for funding more activities from user fees.
- Petroleum-based fuels may become more scarce, or dependence on foreign sources may become too risky, accelerating a switch to non-petroleum fuels.
- Reliance on fuel taxes leaves the door open to proposals to subsidize alternative fuels by taxing them either at a low rate or not at all. The tax incentives provided to gasohol have seriously reduced highway revenues. Not only does the electric vehicle program of Calstart not tax electricity for recharging electric vehicles, but it provides the electricity for free.
- The opportunity to adopt pricing approaches using automatic vehicle identification (AVI) may render fuel taxes redundant or inefficient as a means of pricing travel.
- The transportation program cannot afford to provide full subsidies for alternative fuels and also meet infrastructure funding needs.
- The potential for electric or compressed natural gas vehicles raises the issue that fuel consumption by these vehicles will have to be metered on-vehicle. If meters become widespread on vehicles, the monitoring of VMT rather than fuel consumption would provide a more direct measure of vehicle cost responsibilities.
- Reliance on fuel taxes cannot address all equity concerns among types of vehicles. The variations in fuel consumption per mile among types of vehicles may not correspond to the responsibility of those vehicles for highway costs.

- Lower-income households will pay a greater share of a given amount of fuel taxes than they will for many other types of taxes, such as those on income, VMT, vehicle sales, and vehicle value (personal property taxes).

On the other hand, it is also possible that the present reliance on fuel taxes for surface transportation finance might continue indefinitely and perhaps even be strengthened. Reliance on fuel taxes has some important positive attributes:

- The gasoline tax can be collected by states and by the federal government at a reasonably high level up the distribution chain (sometimes at the refinery) since gasoline is used mostly for taxable highway purposes. The higher up the distribution chain that an item can be taxed, the lower will be the compliance costs, administrative costs, and opportunities for evasion.
- Fuel taxes are relatively easy for the final household consumer to observe; the price of fuel is higher because of the tax, but there is no compliance burden of extra time or paperwork. This is much different from registration fees or income taxes, for which the individual (or household) must fill out paperwork and process payments.
- There have been some other favorable developments from the standpoint of transportation administrators. Ten states now have a variable-rate motor fuel tax (*1*). Most states with variable rates have floors or ceilings (or both) on these rates.
- At least 15 states have had gasohol exemptions repealed or reduced. However, it is estimated that $450 million in federal revenues but only about $30 million in state revenues (in seven states) continues to be lost to gasohol exemptions (*2*).
- Fuel taxes are at least somewhat proportional to use and somewhat proportional to vehicle emissions, although in each case significant variations occur.
- Use of dyes or markers may reduce evasion of diesel or other fuels, increasing revenues and equity.
- The public is accustomed to taxes on highway motor fuels. All states tax motor fuel, even though all do not levy income or sales taxes.

Some alternatives to gasoline and diesel might be distributed, sold, and taxed in the same way that gasoline and diesel fuels are today. These alternative fuels include liquid fuels such as ethanol, methanol, and cleaner-burning distillates of petroleum. If any of these becomes the principal substitute for current fuels, and if the technology of its production and distribution evolves so that taxes can be levied at relatively few points in the wholesale transaction process, then there may be little reduction in the reliance on motor fuel taxes for surface transportation finance. This may be true even if three or four types of fuel capture significant segments of the market.

The Larger Picture

As far as the revenue-related issues themselves, continued reliance on motor fuel taxes has some pluses as well as minuses. But the great level of concern now expressed by many top transportation administrators is not motivated by the relative attributes of the different revenue sources themselves: it is the concern that the overall system of providing and financing surface transportation is not working. Transportation agencies are not achieving the resource levels they need to provide service levels that best support the economic, environmental, and mobility interests of their consumers. The clients of the agencies—the consumers—are left with less mobility, less economic development, and a lesser environment by the forgone programs and projects.

The revenue-related concerns and the revenue alternatives must be evaluated in this broader context of whether the entire system is (or will become) broken. The key issue is whether the transportation agencies and their customers have a desirable and agreed-upon "contract" for what the system should produce for the customers.

What would be a desirable contract between the agencies and consumers? It would provide for a way through which agencies and consumers (the public, households, businesses) could agree on a level of service and performance measures, and through which the consumers could understand what they were buying for the fees that they paid. It would provide for investments in transportation that achieve the levels of service and meet the economic, environmental, and mobility performance objectives that the consumers desired and for which they are willing to pay.

Agencies must be able to explain to their consumers what they are buying in order for this contract to operate. They need to explain how the programs funded by the revenues relate to the economic, environmental, and mobility objectives and to show what can be bought at other levels of revenue.

When viewed in this way, the system *is* broken and the revenue link is a key malfunctioning element of the break. Actions necessary to fix the overall system, and its revenue component, are described in the following.

New Contract Between Agencies and Their Customers

This section describes a recommended approach to financing surface transportation at local, state, and federal levels that provides for surface transportation financing to perform a positive and critically important role in economic growth, environmental preservation, and mobility enhancement.

The new approach—the surface transportation economic, environmental, and mobility (STEEM) approach—ties surface transportation financing to economic growth, environmental preservation, and mobility enhancement by keying financial, investment, and management strategies to economic, environmental, and mobility goals and performance objectives. Different agencies and different levels of governments are allowed to choose their own appropriate emphasis on economic, environmental, and mobility concerns. The approach is grounded in the unique functions that surface transportation capital and management actions serve for private consumers and businesses.

Such an approach to financing transportation can be used to explain to the public, and to administrators and legislators, how their interests as consumers and as constituent representatives will be met through proposed surface transportation fees, investments, and management actions. Agencies are given a method to develop programs, revenue sources, and funding levels that can be demonstrated to be in the best interests of their customers.

The STEEM approach chooses finance sources and fee levels on the basis of their benefits to consumers and the society. It thus differs from the current approach, which is based on tradition and on incremental changes in fee structures and rate deliberation at irregular intervals of time.

In this way a new contract will be forged between agencies and their customers, one in which the customers have a greater understanding of their stake in the agencies' programs, finance sources, and overall investment and management actions.

Relationship to ISTEA

The new approach to keying surface transportation finance to performance objectives and to consumer interests will be an integral element of implementing ISTEA and its state and metropolitan area management systems. In turn, the management systems called for by ISTEA will provide the analytical capabilities that will support the integration of decisions on surface transportation finance with the setting of performance objectives. ISTEA management systems for congestion, safety, pavements, bridges, public transportation facilities and equipment, safety, and intermodalism will provide the basic information on how program levels will relate to the achievement of objectives.

How It Will Work

Agencies will determine surface transportation financing levels, programs of investment, and management strategies in the new approach by choosing financing sources that are consistent with chosen mobility, economic, and environmental objectives and by setting finance levels necessary to achieve those objectives. Agency top management and legislative bodies will target finance sources to each set of objectives—economic, environmental, and mobility—and will base fee levels on performance objectives. Fee and tax levels will be indexed and set so as to achieve these objectives. The fee levels will be adjusted in the next agency budget cycle if the levels of performance differ from the selected objectives.

The new approach is illustrated in terms of the ways in which it incorporates surface transportation finance as an integral tool in achieving major economic, environmental, and mobility objectives; it is driven by an emphasis on the ways in which these areas of concern affect the consumers of agency services.

Surface transportation capital facilities and management strategies exist not for their own sake but for the sake of consumers of transportation and consumers of environmental quality and mobility, and the new approach recognizes this. Transportation capital facilities and management strategies can leverage enormous consumer benefits in terms of operating costs, economic development opportunities, and environmental and livability benefits. Surface transportation finance and programs have been recognized in past approaches to be tied integrally to mobility objectives, which are also incorporated by the new approach.

Economic Objectives

Public investments and management expenditures for surface transportation (on highways and on surface mass transportation) now total about $80 billion/year and largely determine the level of surface transportation operating costs that consumers will pay. Currently, as given in Table 1, consumers pay about $1 trillion/year in direct costs of operating surface passenger and freight transportation and incur another $1 trillion/year in travel time and unreimbursed safety costs. Public agency expenditures of $80 billion/year may seem substantial, but they are only 4 percent of the private total surface transportation costs, which total more than $2 trillion/year.

Freight expenditures are a large portion of total expenditures—more than a third of total transportation expenditures in Table 1—and highway freight expenditures are by far the largest category. The importance of highway investment and of the highway freight industry to the economy of the nation is, however, much greater than as a portion of expenditures. It is imperative for consumers and for the overall economy that the level of public agency expenditures be determined by the impact of those expenditures and management actions on these enormous private costs, not by the impact on the 4 percent that are public-agency costs. The public sector supplies, from its modest share, very important elements of the transportation system that are critical in determining overall user costs and user mobility levels as well as other economic benefits and environmental impacts.

Analyses of user benefits from higher levels of investment in highway programs have shown very high direct returns, and similar returns have been shown for some transit economic analyses. This type of analysis, using the Highway Economic Requirements System (HERS) and related procedures, needs to be regularized at both state and federal levels.

Economic objectives will be defined so as to set user fees and taxes at levels that achieve specified rates of return on those investments to the users or consumers of surface transportation. Programs that provide desirable rates of economic return to surface transportation consumers and to society will be funded. Rates for fees to finance these programs will be set so that programs and projects with the specified highly positive returns can be funded within a given number of years.

For highway programs, states and regions can use procedures such as the ISTEA management systems and HERS to identify investment levels and programs with the desired direct user benefits. HERS selects highway improvements on the basis of economic returns that include

TABLE 1 Passenger and Freight Transportation Expenditures

Mode	Amount, 1990 ($ million)
Passenger Expenditures	
Automobiles and light trucks	510,539
Urban bus	8,290
Taxi	7,455
School bus	7,500
Urban rail	8,290
Intercity rail	4,522
Air	73,536
Water	936
Total, passenger	623,068
Freight Expenditures	
Truck	272,400
Bus	165
Air	13,712
Oil pipeline	8,400
Rail	30,403
Water	20,642
Other	5,992
Total, freight	351,714
Total, passenger and freight	974,782

private user costs. Illustrative analyses using HERS have shown that state highway investment programs at higher levels of expenditure than today's can yield very high returns to users—with some annual benefits from increased investments at 7 to 10 times the increased annual costs.

For public transportation and transportation demand management, the ISTEA management systems will provide performance information for keying to fee levels, investments, and actions. Special analyses applied to overall urban area transit investments have shown similarly high economic returns as those cited for highways developed with HERS. A study of rehabilitating the SEPTA Public Transportation System in the Philadelphia area concluded that the economic return to the state and regional economies from rehabilitating the transit system would be nine times the cost of the rehabilitation.

A distinguishing characteristic of the economic returns from such highway and transit improvements is that the benefits are diffused throughout users of surface transportation and others indirectly affected. No single person or firm can capture all the benefits of those improvements. Government agencies at all levels are the appropriate "investment bankers" for

overall programs, although some private finance sources could be applied and integrated. The key point is that the government agencies begin to view their investments and management actions as aimed at decreasing the costs of operating surface transportation or at increasing the productivity and competitiveness of the overall private sector, both firms and households.

For example, if $1 billion of additional surface transportation funds spent by public agencies can leverage $3 billion in reductions in private costs, then the transportation system as a whole can free $2 billion for use in the rest of the economy.

Besides the direct impacts on user costs, surface transportation capital and management investments affect opportunities for economic development and private-sector productivity. Some studies of highway and transit improvements reach solid conclusions that the improvement generates opportunities to expand and reorient activities, with added non-user benefits. The non-user benefits have sometimes been as large as the direct benefits.

Some other estimates of overall benefits of transportation investments that are based on modeling of economic relationships, such as those of David Alan Aschauer and Alicia Munnell, have concluded that surface transportation investments may be among the most important actions that determine the overall economic growth of nations and states. Although the results of such analyses have been debated, there is no doubt that there can be additional and positive non-user economic benefits from surface transportation capital investments and management actions.

Indirect or non-user economic impacts should be included in setting goals and evaluating desirable levels of surface transportation finance. This will require specialized studies to determine the level of such benefits that might be anticipated in a specific context.

Basing highway investment decisions on economic benefits will have notable highly positive impacts on the trucking industry in at least two ways. First, projects that provide economic benefits will be undertaken, and such projects will help to reduce industry costs and open up markets. Second, benefits-based investment is consistent with benefits-based taxation. The motor carrier industry will have responsibility for providing a smaller share of highway revenues under benefits-based taxation than under currently used cost-occasioned approaches to highway cost allocation.

Table 2 indicates how benefits-based taxation could reduce the cost responsibility for larger trucks compared with automobiles, by comparison with other approaches for allocating highway costs. For a typical state pattern of expenditures, heavier vehicles have a lower cost responsibility per mile than automobiles under the benefits-based approach than under federal or incremental highway cost allocation procedures.

Environmental Objectives

Some states or urban regions may wish to integrate surface transportation finance with the achievement of environmental or livability goals and objectives. Fees related to the environment would be designed to achieve clean air objectives by providing that fee levels will be set and adjusted on the basis of the estimated levels necessary to contribute to achieving necessary reductions in emissions.

The seriousness of environmental problems such as air pollution from motor vehicles varies substantially across the country and within states. Air quality regions are classified by the Environmental Protection Agency in categories ranging from compliance with standards to severe or extreme nonattainment. The Los Angeles region, which has the worst problems, is giving serious attention to emissions fees based on VMT. The so-called smog check emissions tests of vehicles exhausts are already conducted on each vehicle in the Los Angeles air basin.

The new approach to using surface transportation finance as an integral part of achieving environmental objectives in particular areas will be to set fees such that they kick in or are raised when scheduled reductions in transportation emissions are not being achieved. The emissions-based fees can be used to fund programs and projects that could further reduce emissions, thus adding to the impact of the fees themselves in encouraging cleaner vehicles, fewer vehicle trips, and reductions in VMT.

TABLE 2 Total State Level Expenditures Cost Responsibility Ratios per Vehicle Mile (automobile = 1.0) (*8*,p.12)

Vehicle Type	Federal	Incremental	Benefits*	Marginal**
Automobiles	1.00	1.00	1.00	1.00
Pickups/vans	1.12	1.12	1.05	1.00
Two-axle, six-tire	1.75	1.76	1.81	1.30
Three-axle single unit	2.51	2.50	2.09	1.90
Three-axle combination	1.90	1.95	2.09	1.90
Four-axle combination	2.21	2.19	2.09	2.10
Five plus-axle combination	3.48	3.05	1.67	3.10

NOTE: The federal and incremental highway cost allocation methods are those traditionally used to determine the cost responsiblities of different vehicle classes. A benefits-based approach would allocate costs on the basis of relative benefits received. The marginal cost approach would apply congestion pricing and pavement damage pricing.

* Benefit-based program mix is different than federal/incremental mix.

** Marginal social cost is overall rather than capital, and there is no comparable program mix with this approach. The marginal social cost approach would imply $220 billion in user fees at the national level, about four times as much as current user fees.

Mobility Objectives

Transportation programs serve basic mobility objectives. Routine highway and transit maintenance and rehabilitation keep facilities in service and maintain mobility for the users, even if they are not associated with changes in user costs or in emissions. Transit service preserves mobility for many who have no viable alternative means of travel.

In most places the preservation of basic mobility is already recognized as being tied to surface transportation finance. For the mobility objective, only modest changes in current programming and budgeting information are required. To put together a budget under the new financing approach, the agency determines which programs and projects are necessary to meet the economic, environmental, and mobility objectives and identifies a level of overall fees that will provide the necessary financial resources for the investment programs. This is not an exercise that most agencies have already undertaken, but it can be done before the ISTEA management systems are fully operational and will be readily accomplished when they are implemented.

Feasibility of New Approach

Has this approach ever been tried? Except for the tie-in of the specific financing sources indexed to the objectives, it has already been applied in developing and selecting Oregon's Statewide Multimodal Plan. Table 3 presents the performance of alternative plans with regard to public costs, private costs, and major environmental, economic, mobility, and other objectives.

TABLE 3 Summary Evaluation of Sketch Plans, Oregon Transportation Plan

Criteria	Low Funding	Current Programs	Livability/ Economic	Best Plan?
Highway VMT (million)				
Urban	25,100	25,100	19,800	?
Rural	19,300	19,300	19,300	?
Total	44,400	44,400	39,100	?
Transit trips (million)				
Urban	109	108	212	Livability
Intercity	1.4	1.5	3.0	Livability
Private cost ($ billion/year)	33.4	32.6	31.6	Livability
Public cost ($ billion/year)	1.1	1.2	1.7	Low funding
Total cost ($ billion/year)	34.5	33.8	33.3	Livability
Economic efficiency	Worse than 1992	Same as 1992	Better than 1992	Livability
Economic development	Worse than 1992	Same as 1992	Better than 1992	Livability
Environmental	Negative	Negative	Positive	Livability
Land use	Neutral	Neutral	Positive	Livability
Alternative modes and technologies	Neutral	Neutral	Positive	Livability
Consistent with Oregon policies	No	No	Yes	Livability
Safety	Worse than 1992	Same as 1992	Better than 1992	Livability
Summary	Worse than 1992	Same as 1992	Better than 1992	Livability

The table clearly illustrates that a plan developed to meet both environmental and economic objectives can be superior on virtually all measures to business as usual or a continued decline in funding (which would occur if revenues were never adjusted for inflation). The plan included in the preferred alternative many investments that were helpful to both environmental and economic objectives, because many such investments or programs were found to have positive impacts on all these goals.

Revenue Sources for New Approach

Revenue sources for the new approach should also be tied as closely as possible to the objectives being served. An emphasis on economic impacts will be most consistent with the application of mileage fees or congestion and pavement fees. The new approach makes a variety of types of taxes and fees appropriate for supporting economic or mobility objectives:

- VMT fees, with variations by type of vehicle to achieve equity on the basis of benefits (or costs);
- Vehicle registration or use fees, perhaps graduated by value for light vehicles as well as by weight for heavy vehicles;

- Vehicle sales taxes;
- Congestion or peak/off-peak fees or fares (differentiated by facility and time of day);
- Pavement damage fees (if used to set overall VMT fees); and
- Fuel taxes, if applied equitably among fuel types.

Selected fee levels for the next budget period are accomplished by using a predetermined index that will result in sufficient revenues (from the sources being used) to achieve the objectives of the program. Revenues per vehicle mile or other unit will be set differently for different vehicle classes in order to achieve equity. Agency top management and legislative officials will agree on the performance objectives and fee indexes for the budget period that are necessary to achieve those performance objectives.

Mileage-based fees are particularly suited to the overall approach because they can be set proportionally to benefits generated per mile by the anticipated program of investments. Programs of investments will be selected on the basis of total benefits to all user classes, although considerations of equity among vehicle classes could be used in their selection. Once programs are selected, the economic analysis can also estimate the benefits generated per mile of travel for each type of vehicle. Mileage-based fees could be set for the vehicle classes in relation to the anticipated benefits per mile of travel for those vehicle classes.

Although an assessment of benefits per mile is most consistent with the application of the new approach, relative user fees could also be based on a cost-occasioned approach, the traditional means in U.S. studies of setting relative levels of fees for different types of vehicles. A cost-occasioned fee structure will assign higher relative costs to heavier trucks than will the benefits-based approach.

Emissions fees to support environmental objectives could also be collected on a variety of bases:

- VMT,
- Congestion,
- Vehicle sales,
- Vehicle registration, and
- Trips (fees on start-ups of vehicle engines; vehicles starting up cold emit very high emissions when starting up, with current emissions control technologies).

Emissions-based vehicle sales or registration fees are examples of the kinds of current fees and taxes that could be graduated on the basis of emissions tests and integrated into programs to achieve environmental objectives. The emissions-based VMT, congestion, or trip fees could be implemented as new types of fees with more direct relationships between the individual vehicle's fees due and the total emissions of the vehicle than would sales or registration fees.

Role of Motor Fuel Taxes

The new approach does not preclude continued reliance on motor fuel taxes, particularly in the short term, when the technological opportunities to implement some of these other taxes, such as VMT fees or congestion fees, may be limited. Motor fuel taxes have been adjusted by the federal government and some states to differentiate use by larger versus smaller vehicles. The federal diesel differential, a higher tax rate for diesel fuel than for gasoline, is intended to make up for the relative lack of equity of federal taxes among vehicle classes if gasoline and diesel are taxed at similar rates.

To evaluate a reasonable future role for motor fuel taxes, three overall surface transportation revenue alternatives have been postulated (general options suggested by David Greene, Oak Ridge National Laboratory):

- Muddle through,
- Index motor fuel taxes to inflation or needs, and
- Monitor vehicle travel using high technology.

Each of these alternatives is evaluated with regard to how well it can correspond to the recommended new approach, and against general tax policy criteria of adequacy, equity, efficiency, and simplicity. Finally, specific implications are identified for the motor carrier industry.

Muddling through provides for no overall strategy to adopt a new approach or to select tax sources that can provide adequate, stable, and equitable financing. For the motor carrier industry, muddling through presents the continued threat of never investing properly in highways and accepting less-than-desirable levels of performance and conditions. This will result in higher-than-necessary costs of operation and inefficiencies in the distribution of goods. The motor carrier industry will be unable to do as much as it might have done to enhance the competitiveness of overall U.S. industries.

Indexing either fuel taxes or VMT taxes to the expenditures necessary to meet economic, mobility, and environmental goals provides for a better outcome in terms of service levels and overall costs for passenger and freight transportation. The choice between fuel taxes and VMT taxes should be based on all of the attributes of those two tax sources.

The motor carrier industry has favored taxation of fuels rather than VMT. Fuel taxes do not lend themselves well to very steep graduation of fee schedules for heavier vehicles, which could result under some procedures for allocating highway cost responsibility. There have been some very steep graduations estimated for cost responsibility per mile, particularly in federal studies using the federal method. The ratio of cost responsibility per mile for heavy trucks to that for automobiles has reached 16 to 1 in some federal studies. Since fuel consumption per mile varies by only up to 3 or 4 to 1 for heavy trucks relative to automobiles, fuel taxes by themselves are not very adaptable to achieving such ratios (even with the modest diesel differential). Therefore, the motor carrier industry perceives less risk in a future in which fuel taxes continue to play a major role in surface transportation finance.

With a focus on generating user and other benefits, and with a benefits-based approach to setting fees, the motor carrier industry will probably be better off than it is today under either indexed fuel taxes or VMT fees. A benefits-based taxation approach will provide for generally lower tax responsibilities for heavier vehicles than current cost-occasioned approaches. If Table 2 provides guidance, state taxes per mile for heavy vehicles under benefits-based taxation could be about half what they are under cost-occasioned taxation.

Under an approach to benefits-based taxation, the relative cost responsibility for heavier trucks per mile of travel may be less than would be generated by per-gallon fuel taxes. If the cost responsibility per mile for the heaviest trucks was less than 2 to 1, and the revenue generated was 3 or 4 to 1 relative to automobiles, heavier trucks could overpay substantially. This suggests that a future reexamination of whether the industry favors fuel taxes or VMT taxes may be desirable.

Summary Evaluation of Motor Fuel Taxes and VMT Fees

Motor fuel taxes and VMT fees could each play a strong role in the new approach, depending on time and advances in technology. A brief summary is provided of how motor fuel taxes and VMT fees stack up with regard to the important criteria for evaluating tax sources. These criteria include consistency with the new approach, adequacy, simplicity, equity, relationship to efficiency, and ease of implementation. From this review, it is concluded that motor fuel taxes are the easiest to administer but that overall equity could be enhanced if taxation were on the basis of vehicle miles rather than fuel consumption.

Taxes on Current Motor Fuels

Taxes on current fuels may be continued if other broad-based taxes are not implemented and if the use of fuels for highway travel does not change dramatically. Gasoline and diesel revenues now account for 75 percent of federal highway revenues and nearly 60 percent of all state expenditures (when federal and state fuel taxes are taken into account).

Adequacy

Consistency with New Approach

Current fuel taxes are partially consistent with the new approach, although they do not provide for the consistency between revenues and benefits that other taxes based on mileage would provide.

Adequacy and Tax Rates

Current tax rates on diesel and gasoline vary across the states. Although most tax rates are set at a fixed per-gallon figure, taxes are also indexed on the basis of price (with a minimum and a maximum per gallon) or a cost index. Diesel and gasohol rates sometimes vary from the rate for gasoline.

The noted problem with current fixed-rate, per-gallon fuel taxes is that they automatically become less and less adequate because they do not respond to inflation; they can also become less adequate if fuel efficiency increases, dropping revenue per mile of travel in current as well as constant dollar terms.

Table 4 presents the fuel used, fuel efficiency, and VMT per vehicle for household-owned vehicles included in the 1988 residential energy consumption survey by the U.S. Department of Energy. This data source for VMT may be more reliable than others, such as the National Personal Transportation Study, because the vehicle mileages are based on odometer readings rather than on self-reported trips and mileage.

As is apparent, fuel efficiency by model year for household-owned vehicles increased substantially in the early 1980s, after which it leveled off. The leveling off is partly due to no further changes in the corporate average fuel economy standards for automobiles and light trucks, as well as the penetration of light trucks into the light vehicle market to the point that they now account for about half of the net increase per year of household vehicle holdings.

TABLE 4 Variations in VMT and Fuel Consumption per Vehicle by Model Year, 1988 (9,p.34)

	Number of Vehicles (million)	Vehicle Miles of Travel	Fuel Consumed (gal)	Fuel Expenses ($)	Miles per Gallon
Model Year			(average per vehicle)		
1988 or 1989	7.1	12,920	583	589	22.1
1987	12.0	13,408	584	585	22.9
1986	15.5	12,570	573	575	21.9
1985	13.2	12,074	569	572	21.2
1984	13.3	11,506	552	548	20.9
1983	8.1	10,610	504	503	21.1
1982	8.1	10,752	506	506	21.2
1981	8.4	10,021	499	596	20.1
1979 or 1980	17.0	9,480	572	565	16.6
1977 or 1978	15.7	8,715	600	584	14.5
1975 or 1976	9.9	7,706	594	571	13.0
1974 or earlier	19.3	6,271	528	489	11.9

Table 4 indicates that further increases in average fuel efficiency are definitely coming, because older vehicles, which are less fuel efficient, will eventually retire. In fact, the fuel consumption per mile of the vehicles of model years 1974 and earlier is about twice that of the more recent vehicles. These older vehicles will be retiring rapidly throughout the 1990s—in fact, since the data are for 1988, many have already retired. For this reason, short-term increases are expected in fuel efficiency in a manner that will reduce motor fuel revenues per mile of travel.

Whether fuel efficiency will change in the future depends on both energy prices and regulatory policies. Because motor fuel prices are so low in the United States, and because the fuel efficiency of automobiles in other countries with much higher energy prices is about equal to U.S. passenger car fuel efficiency, it is unlikely that increased fuel prices will have any impact on U.S. automobile fuel efficiency. However, higher fuel prices may affect the relative sales of automobiles and light trucks, leading to slightly better fuel efficiency for the overall light vehicle fleet in future years.

Taxes on current fuels (gasoline, diesel, gasohol) could be altered to make them responsive to inflation or to indexed revenue needs under the recommended new approach.

Stability

Taxes on current fuels require revisions in rates periodically to respond to inflation or needs. In addition, the potential for changes in fuel efficiency will further decrease the stability of fuel taxes. Fuel taxes have recently been less stable than taxes on VMT would have been or than taxes on vehicle registrations have been.

Appropriateness for Dedication

Taxes on current fuels are clearly appropriate for dedication.

Simplicity

Point of Taxation

Taxes on current fuels are paid by the fuel distributor or at the refinery. Even with indexed rates, taxes on fuels dispensed through gasoline service stations would continue to be collected through means similar to those for gasoline or diesel fuels today, and as far up the chain of distribution as feasible.

Compliance Costs

Compliance costs should continue to be similar to those for gasoline or diesel fuels today. For the eventual consumer of gasoline dispensed from the pump, compliance costs for gasoline taxes are very low. Costs paid simply include the tax, and no filings or paperwork are necessary. Compliance costs for energy companies, which are the major payers of gasoline taxes, are also low, because taxes are paid on a large amount of product.

Compliance costs for motor carrier fuel taxes are significant to the taxpayers. All states are now to join the International Fuel Tax Agreement (IFTA), which will cut down substantially on carrier filings with regard to motor fuel tax accounts in various states.

Potential for Evasion

After a long period of neglect, evasion of motor fuel taxes has become a topic of serious concern. Evasion of any existing tax is difficult to estimate, because revenue figures are the most carefully collected data and other data must be analyzed in order to refute the estimates of fuel consumption based on the revenue figures. However, it has been estimated that $1 billion/year is lost in gasoline tax revenues. The same amount is estimated for lost diesel revenues, which if correct means that 15 to 25 percent of current diesel taxes are being evaded. FHWA has

initiated a cooperative effort with the Internal Revenue Service (IRS) and the states to curtail the evasion of motor fuel taxes.

All previous estimates indicate that evasion of diesel fuel taxes occurs at a generally greater percentage rate than evasion of gasoline taxes. This is generally attributed to several major factors:

- Diesel fuel is a similar product to Number 2 heating oil, and very large quantities of this product are available on a non-taxed basis.
- Diesel fuel is taxed lower down the distribution chain, primarily because of the previous factor.
- Many more taxpayers are responsible for remitting diesel fuel taxes than are for gasoline taxes.
- Where diesel fuel is taxed at a higher rate than gasoline, as at the federal level and some states, added incentives are created because more can be saved by evading higher rather than lower per-gallon taxes.

Table 5 gives estimates made by the states of the evasion of motor fuel taxes, as part of the AASHTO Study of Motor Carrier Taxation and Registration Issues (*3*). The evasion rates for regular gasoline taxes were estimated to be much lower than those for carrier fuel use taxes. The rates in Table 5 were estimated before FHWA began to encourage more attention to fuel tax evasion.

Over the past several years there has been growing recognition of the magnitude of the problem of fuel tax avoidance and evasion, and several initiatives have been taken to address the problem:

- NCHRP performed a synthesis of current practice on measures to curtail evasion (*4*).
- IRS has been undertaking a nationwide effort to expose organized tax evasion schemes and has uncovered several large operations in Texas, Virginia, New York, and other states.
- Congress has created a funding program for IRS and the states to improve the level of enforcement of fuel tax collection. The state assistance program is administered by FHWA.
- Training courses have been conducted by the Federation of Tax Administrators and member state agencies on fuel tax evasion, auditing, and investigation techniques.

TABLE 5 State Estimates of Evasion of Motor Fuel Taxes

State	Regular Motor Fuel	Carrier Fuel Use
Arizona	Very small	Very small
Arkansas	Less than 1% at pump	Less than 1% for decals; 10 to 15% overall
Colorado	Difficult to evade	1% to 5%
Iowa	Not a problem	0.4%
Maine	Less than 1% at pump	15% to 20% prior to supplier law
Maryland	Minimal	Indiscernible
Nevada	0 to 3%	5%
New Hampshire	1 to 3%	1 to 3% for New Hampshire; 15 to 20% for out of state
Ohio	Almost none	Not applicable
Virginia		30%

• FHWA has contracted for a study, through the Transportation Systems Center, of a possible national fuel dyeing or chemical marking program, based on the successful experience of some Canadian provinces and related programs in other countries.

Two other initiatives hold out the possibility of substantial reduction in avoidance and evasion in the next few years as a result of ISTEA: (a) the requirement that all states, in effect, must become members of IFTA or a multistate agreement that functions like IFTA, and (b) the commercial vehicle operations (CVO) component of the IVHS program could lead to the development of systems designed to reduce evasion of fuel and other taxes.

The primary thrust of the effort to make IFTA a national system has been driven by a desire to reduce the burden of fuel tax registration and reporting on motor carriers. To facilitate the achievement of this objective, Congress appropriated funds to help states develop the necessary mechanisms to administer and enforce fuel tax collection under a base state system. If this effort is well-planned and executed through the National Governors' Association (NGA) working group that has been established to coordinate the states' efforts, fuel tax collection and enforcement programs could be greatly improved.

The IVHS/CVO program provides an opportunity to further this objective if it is effectively coordinated with the NGA program and the other tax enforcement initiatives. This might be done in various ways, and possible approaches are just being conceptualized under a separate contract with FHWA (*5*). One system being considered is a national data base on all carriers and vehicles covered by IFTA that states could access to determine the base state of any vehicle covered by the program. Such a national data base for IFTA carriers and vehicles could be accessed routinely by state fuel tax administrators, auditors, investigators, and possibly by weighmasters at weigh stations and inspectors at ports of entry. To minimize the regulatory burden on carriers and state inspectors, various IVHS/CVO projects are under way involving the use of AVI transponders to pre-clear trucks with proper credentials so that they do not have to stop at these weigh stations and ports of entry. Vehicles could be screened by checking the national data base, either on a sample basis, selectively based on the judgment of officials in the field, or possibly for each interstate carrier's truck.

Once a system such as this is fully operational on a national basis, there would probably be sufficient incentive for most interstate carriers to use the AVI transponder system, and tax enforcement would be greatly improved. Most interstate carriers' trucks would be precleared, and only those trucks without AVI transponders would normally have to be stopped for inspection of credentials and tax status.

Administrative Issues and Costs

Administrative issues and costs will be the same as today. Fuel products must be monitored and subjected to taxation at an appropriate point in the distribution chain—as high up as possible. Federal fuel taxes are highly productive revenue sources with low administrative costs.

The administrative costs for current fuel taxes incurred by the states are given in Table 6. States spend only $200 million administering motor fuel taxes. The administration of carrier motor fuel tax accounts is generally more expensive to the states than the administration of gasoline taxes, as shown in Table 7. For states reporting for both regular motor fuel and carrier fuel use, it is clear that the carrier fuel use taxes are far more costly to administer, particularly when compared with yield. Table 7 also includes three responses by weight-distance tax states, indicating that the administrative costs of weight-distance taxes were also high, comparable to some carrier fuel use taxes.

Equity

Motor fuel taxes do not achieve equity by vehicle class and must be augmented by other fees, generally by fees that place high relative rates on heavier vehicles. However, not all types of

TABLE 6 State Administrative Costs of Fuel Taxes

	Administrative Costs			Receipts \1			Administrative Costs as a Percent of Total Receipts		
	1989	1990	1991	1989	1990	1991	1989	1990	1991
	(1)	(2)	(3)	(4)	(5)	(6)	(1)/(4) (7)	(2)/(5) (8)	(3)/(6) (9)
Alabama	5,322	9,952	10,896	295,058	352,077	342,710	1.80	2.83	3.18
Alaska \2	45	45	41	19,778	45,162	19,464	0.23	0.10	0.21
Arizona	3,966	3,933	3,875	347,334	342,669	371,332	1.14	1.15	1.04
Arkansas	2,148	6,023	6,189	214,820	214,618	219,698	1.00	2.81	2.82
California	6,147	7,503	9,124	1,186,310	1,320,180	1,854,942	0.52	0.57	0.49
Colorado	2,463	3,070	3,542	307,827	319,842	354,165	0.80	0.96	1.00
Connecticut	2,652	3,541	3,039	315,516	306,259	328,802	0.84	1.16	0.92
Delaware \2	261	646	681	65,372	64,134	71,246	0.40	1.01	0.96
DC \2	-	291	3,273	29,221	30,025	30,307	NA	0.97	10.80
Florida	7,373	11,189	12,357	667,393	684,186	963,857	1.10	1.64	1.28
Georgia \2	1,268	1,022	2,092	325,958	329,014	325,701	0.39	0.31	0.64
Hawaii	3,039	1,642	2,073	42,667	43,513	51,556	7.12	3.77	4.02
Idaho	1,165	1,340	1,227	100,488	103,497	117,269	1.16	1.29	1.05
Illinois	16,362	23,577	24,876	810,597	1,052,099	988,402	2.02	2.24	2.52
Indiana	8,985	10,197	9,617	562,946	579,458	580,174	1.60	1.76	1.66
Iowa	1,041	1,935	1,049	302,348	330,222	317,025	0.34	0.59	0.33
Kansas \3	-	2,154	2,510	193,577	222,319	251,077	NA	0.97	1.00
Kentucky	1,694	1,809	1,771	360,279	356,449	348,884	0.47	0.51	0.51
Louisiana	3,648	4,520	3,165	364,789	451,990	437,461	1.00	1.00	0.72
Maine	630	662	709	123,493	120,881	131,460	0.51	0.55	0.54
Maryland	5,869	5,499	6,195	446,928	443,788	438,595	1.31	1.24	1.41
Massachusetts	10,732	11,229	10,539	304,650	350,069	520,633	3.52	3.21	2.02
Michigan	5,707	5,699	5,236	685,035	685,675	681,162	0.83	0.83	0.77
Minnesota	1,673	1,701	1,606	436,758	451,692	439,621	0.38	0.38	0.37
Mississippi	550	578	554	289,089	281,057	277,630	0.19	0.21	0.20
Missouri	1,453	1,845	1,589	356,987	358,702	350,978	0.41	0.51	0.45
Montana	675	678	383	103,699	105,036	104,519	0.65	0.65	0.37
Nebraska	87	79	76	182,035	203,650	217,940	0.05	0.04	0.03

Nevada	1,272	2,270	2,528	140,307	150,241	154,714	0.91	1.51	1.63
New Hampshire	608	607	595	79,188	83,789	93,571	0.77	0.72	0.64
New Jersey \2	3,835	3,738	4,267	426,071	415,297	423,358	0.90	0.90	1.01
New Mexico	868	955	242	144,704	159,168	159,984	0.60	0.60	0.15
New York \2	17,142	19,586	19,587	537,374	537,938	500,922	3.19	3.64	3.91
North Carolina	6,485	10,110	4,334	679,680	832,626	839,337	0.95	1.21	0.52
North Dakota	432	464	488	68,189	69,014	68,270	0.63	0.67	0.71
Ohio	4,181	4,561	3,600	887,426	1,009,824	1,287,107	0.47	0.45	0.28
Oklahoma	5,501	5,290	5,093	316,570	324,098	317,500	1.74	1.63	1.60
Oregon	537	848	686	216,161	244,106	277,328	0.25	0.35	0.25
Pennsylvania	8,862	7,566	6,228	1,008,498	1,018,817	1,054,560	0.88	0.74	0.59
Rhode Island \2	823	78	75	73,446	83,504	97,545	1.12	0.09	0.08
South Carolina	1,693	1,697	1,908	332,983	349,734	345,936	0.51	0.49	0.55
South Dakota	946	1,009	1,601	78,371	80,311	80,435	1.21	1.26	1.99
Tennessee	6,208	6,310	6,127	555,846	596,575	622,692	1.12	1.06	0.98
Texas	15,459	15,512	15,556	1,497,017	1,497,935	1,503,865	1.03	1.04	1.03
Utah	1,637	1,185	990	161,332	165,570	165,967	1.01	0.72	0.60
Vermont \3	-	548	579	-	55,530	57,819	NA	0.99	1.00
Virginia	1,566	1,604	1,534	601,461	633,145	630,081	0.26	0.25	0.24
Washington	2,569	2,705	3,033	453,959	538,321	595,153	0.57	0.50	0.51
West Virginia	1,268	1,474	2,115	136,376	152,119	211,541	0.93	0.97	1.00
Wisconsin	749	944	887	511,710	531,045	548,151	0.15	0.18	0.16
Wyoming	517	624	192	36,968	42,159	43,013	1.40	1.48	0.45
Total \3	178,113	212,044	210,529	18,384,589	19,699,129	21,215,459	0.97	1.08	0.99
Mean \3							0.99	1.02	1.14

- no funds reported

NA not applicable

\1 Amounts exclude adjustments for undistributed balances, funds in transit, etc.

\2 The following states placed most highway-user funds in the state general fund:
1989 Alaska, Delaware, New Jersey, New York and Rhode Island
1990 and 1991 Alaska, District of Columbia, Georgia, New Jersey, New York, and Rhode Island.

\3 1989 state highway finance data not reported for Vermont, administrative costs not reported for Kansas.

TABLE 7 State Breakdowns of Administrative Costs of Regular Motor Fuel and Carrier Fuel Use Taxes (3)

State	Regular Motor Fuel ($)	Carrier Fuel Use ($)	Weight Distance ($)
California	483,000 (0.1%)	2,854,000 (3.7%)	
Florida	1,520,811 (0.4%)	627,847 (18.0%)	
Iowa	NA	442,500 (53.7%)	
Kentucky		769,247 (10.9%)	
Maine	35,000 (less than 1%)	315,000 (11%)	
Maryland	2,811,496 (1.2%)	1,104,229 (9%)	
Mississippi	450,000 (3%)(diesel)	360,000 (3%)	
Nevada	(15%)	(14%)	(12%)
Oregon	1,897,000 (0.3%)		7,810,537 (12.4%)
Tennessee	1,258,000 (less than 1%)	See regular motor fuel	
Virginia	716,372 (0.2%)	4,394,684 (25.7%)	
Wisconsin	800,000 (2%)	80,000 (no net receipts due to Wisconsin's requirements)	
Wyoming	55,000 (less than 1%)		3,408,825 (14%)

alternative fees look better, except VMT fees weighted by cost responsibility. VMT fees are the easiest type with which to achieve vehicle class equity. Vehicle use fees could be indexed by vehicle class to achieve greater equity among vehicle classes than fuel taxes alone could achieve. Vehicle sales taxes will have less equity by vehicle class than fuel taxes.

Relationship to Efficiency

Fuel taxes do not lead to more efficient use of transportation facilities.

Ease of Implementation

Taxes on current fuels may be relatively easy to implement compared with major changes in the revenue structures of the federal government and the states. Fuel taxes at the local or regional levels have not become widespread and should be assumed to be relatively difficult to implement.

VMT Fees

A tax on VMT could be collected for travel within the nation, a state, or regions. An assessment of fees could be based on the reading of a vehicle odometer or hubodometer or on records of vehicle use of roadways recorded through use of AVI equipment. VMT fees could be graduated on the basis of vehicle size and weight. They could also be graduated by other vehicle characteristics, including emissions, equivalent single-axle loads, vehicle value, energy consumption, and energy type.

A VMT fee would be an appropriate state fee that could be adjusted to achieve equity among vehicle classes and vehicles on the basis of their relative cost responsibility. It would be an appropriate federal fee, either with or without parallel state and local VMT fees, but it would be much easier to administer jointly if state or local programs existed that involved monitoring and checking of mileage traveled or mileage accumulated by the vehicle.

(Much of the discussion in the previous section of point of taxation, compliance costs, administrative costs, and evasion levels for registration fees or vehicle use taxes applies to VMT fees. Therefore, the following discussion does not repeat all relevant estimates covered earlier. Where the VMT fee provides for different issues, these are discussed.)

VMT fees could be administered through periodic readings of odometers, hubodometers, or other meters on the vehicle itself. This might be done electronically, if all vehicles are required to have transponders or smart cards, or manually, if representatives of enforcement agencies read the meters.

VMT fees could also be administered in the same manner as congestion fees, with estimates of the mileage of each vehicle built up from a series of interrogations of a transponder or smart card on the vehicle as it traveled on the road system. If the VMT fee is administered in this manner, about the same administrative, compliance, and enforcement costs will be incurred as for the congestion fees.

Adequacy

Consistency with New Approach

VMT fees are very consistent with the new approach. Economic, mobility, and environmental benefits link well with vehicle use.

Adequacy and Tax Rate

VMT fees could yield almost any desired level of revenues. Tax rates could be set at virtually any reasonable level. With more than 2 trillion annual VMT in the United States, VMT fees need to average only about $0.01/mi to yield current federal tax revenues and only $0.04/mi to yield revenues to fund all current state and federal surface transportation programs. Desirable revenue increases under the recommended new approach would raise additional amounts.

VMT fees would most logically be based on the relative cost responsibility of the various vehicle classes. If VMT fees were set to be proportional to the results of the 1982 Federal Highway Cost Allocation Study, the federal fees per mile for the heaviest trucks would be more than 16 times the fees for automobiles. For states, whose expenditures are tilted more heavily toward items that are common costs (and allocated in cost allocation procedures by VMT), the heaviest trucks may typically have cost responsibilities from three to seven times those of automobiles on a per-mile basis. Both federal and state cost allocation studies could set highly equitable VMT fees among vehicle classes.

Stability

The VMT fee tracks with vehicle use by definition. VMT is a reasonable parameter in reflecting some aspects of need. VMT fees are not responsive to inflation, although they could be indexed or adjusted periodically in response to changes in revenue requirements.

Appropriateness of Dedication to Trust Funds

VMT fees are highly appropriate for dedication to trust funds. Since VMT is highly related to the needs for capacity expansion and for system preservation, a VMT fee would tend to track with needs better than current fuel tax sources.

Simplicity

Point of Taxation

VMT fees would be collected on the basis of the individual vehicle or fleet owner and would be incident on vehicle use. Average miles per vehicle are higher for commercial vehicles than for private vehicles and for higher-income persons than for lower-income persons.

The point of taxation and incidence would be similar to that of the registration fee or vehicle use tax. For the states (or for regions if applied on a regional basis), VMT fees could be collected as part of registration fee submittals. Impacts of the fees on VMT will be less if the fees are collected annually than if they are collected more frequently. The highest responsiveness to VMT fees in terms of reduced VMT would come if the driver could see a running VMT fee meter inside the vehicle, which would be a reminder of the costs being incurred.

For the federal government, VMT fees could be paid through federal income tax forms by the filers of those forms. Thus, about 90 million to 100 million filers are anticipated. Cross checking with state registration information, and with state and local observations of mileages, will be desirable for federal fees.

Compliance Costs

Compliance costs will include the costs estimated for registrations and for vehicle use fees, plus the costs associated with basing the tax paid on miles of travel. These extra compliance costs will include reading a meter and recording mileage.

It has been assumed that mileages can be voluntarily read by the taxpayers at the time of recording of the vehicle license, identification number, and ownership information on state registration forms or federal tax forms.

Filing of VMT reports with state registration forms should take taxpayers no more than 15 min if done on an annual basis. It is assumed that this cost applies each time a registration form is sent in. Thus, considering used vehicle purchases, about 200 million forms might be submitted each year to the states, which at a cost of $10/hr would amount to $167 million to $500 million/year in state VMT fee compliance costs for consumers.

The costs of filing federal VMT forms are estimated at $500 million to $750 million/year, the same estimate as for vehicle use taxes that require recording the vehicle's age and model year. These costs are higher than the state costs because this filing requires a new form and new activities to comply and is not an add-on to existing registration fee submittal activities.

For either state or federal VMT fees, the taxpayer will probably read a table that indicates the tax due on the basis of miles of travel. For vehicles scrapped or sold during the year, the mileage must be recorded at the time of scrappage or sale and then reported. This process will be facilitated by having reports filed of mileage readings (of the meters) by those who have just purchased a vehicle and by those businesses that scrap vehicles.

The added compliance costs for VMT fees are based on the assumption that an odometer, hubodometer, or other meter is put into each vehicle (new or old), with the device in the vehicle designed or installed so as to prevent tampering. No technology can be fully tamper-proof, but the use of coded seals and the imposition of very high fines for tampering could discourage tampering by making detection relatively easy and penalties severe.

Technologies to consider include any type of meter, smart cards, or transponders. Meters could also include transponders or smart cards in them, to be read electronically by roadside interrogators or at inspections stations.

According to hubodometer suppliers, hubodometers are available for $30 to $40 for heavy vehicles. They cost the same price for lighter vehicles, although they are not widely applied to

lighter vehicles. The costs are estimated to decline under universal application. An estimate of $30 to $40 per vehicle (equipment plus installation) is used as the basis for compliance costs, assuming either a newly installed hubodometer or another type of meter or treatment of the odometer to prevent disconnection or rollback. It is assumed also that the hubodometer includes a transponder or smart card that provides for electronic interrogation. A hubodometer is assumed to be the mileage-recording device because standardized and controlled hubodometers could be retrofitted to all vehicles, without concern about accuracy variations among existing odometers on the vehicles.

The cost for hubodometers is in addition to those compliance costs listed for the vehicle use fee. This cost is based on the assumption that mass market savings are partly offset by the costs to make hubodometers or other meters more tamper-proof and capable of being read electronically. Currently, hubodometers break if opened for tampering, but they can be removed from the wheel.

An option is to rely on self-reporting without much opportunity for backup information. This is not believed to be a wise course of action, since it creates incentives for underreporting and consequent equity issues between honest and less-than-honest taxpayers.

A fleet of 180 million vehicles will require $5.4 billion to $7.2 billion, at $30 to $40/hubodometer or other meter, in first-year compliance costs. Costs within a state or region are proportional to the number of vehicles. Assuming an average of 10 years of life for hubodometers or other meters (similar to vehicle lives), and 17 million new and 3 million replacement hubodometers per year at a cost of $30 to $40, the total annual cost of the hubodometers, on a national basis, will average $600 million to $800 million after the first year. (These costs are in addition to the $167 million to $500 million annual costs estimated for states and $500 million to $750 million annual costs estimated for states plus federal paperwork filing costs.)

The total national compliance cost will thus range from $6.1 billion to $8.5 billion in the first year (start-up) and $1.3 billion to $2.1 billion annually thereafter.

Evasion

Evasion would be a major concern, because the VMT fee would be paid on the basis of the individual vehicle and because more complex record keeping is required than that of whether a vehicle exists.

Estimates made of evasion of state weight-distance taxes range up to 30 percent. It has been assumed that highway agency and FHWA estimates, which are at 10 percent or less, have more credibility than other estimates. Under this assumption, evasion is estimated at about 10 percent, on the basis of the observation that current evasion rates for state weight-distance taxes are estimated to be near 10 percent (6).

Administrative Issues and Costs

VMT fee enforcement would require reading of odometers or other meters, or monitoring of vehicle movements. Odometers are currently read each year in California as part of emissions checks. However, with additional incentives for altering odometers, technological changes in odometers, or the use of hubodometers or separate meters, it would be desirable to improve the enforcement and equity of VMT fees. Additional administrative costs would be incurred to read or to check meters if the vehicles are not otherwise subject to inspection.

The meters could be read visually or electronically during vehicle inspections at centrally administered inspection stations or during highway patrol or parking enforcement activities by state or local personnel. Having personnel of private service stations read the meters under a decentralized inspection system is not likely to be a valid enforcement approach.

For areas that do not have government-administered vehicle inspections, additional costs will be necessary to ensure some level of monitoring of compliance with VMT fees, such as a required periodic reading by a government agent with the paperwork signed as to the accuracy of the reading and the lack of tampering. This would imply a very large cost, and random inspections should be considered as an enforcement procedure. Random inspections, in association with other enforcement by states, are assumed to cost $1 million/state/year (based

on average 20 full-time equivalents at $50,000/year each). This cost is assumed to be picked up by the federal government, as with the use tax.

Assuming random inspections at parking lots, meters, and so forth, state and local personnel could provide a significant deterrent to evasion. Federal checking of meters is probably an unlikely administrative approach.

If mileage readings are included in state registration information and state titling records, there will be additional state record-keeping costs. These costs are estimated to be another 2 min/vehicle/year, or $120 million/year (180 million vehicles at 2 min/vehicle at $20/hr), which would add $120 million in state costs to the $120 million estimated for state cross checking with regard to any federal vehicle use fees. Total state costs would thus be about $240 million/year.

Federal costs are assumed to be the same as for the vehicle use tax, or $150 million to $217 million/year. It is assumed that the federal government will reimburse state costs if states are not administering VMT fees. Total administrative costs are estimated at $390 million to $457 million/year.

Equity

VMT fees can be designed to be equitable among or within vehicle classes. VMT fees can be graduated on the basis of cost responsibility, vehicle size and weight, equivalent single-axle loads, value, emissions, or other characteristics, and thus VMT fees allow for a close approximation between vehicle payments and vehicle cost responsibility. As presented in Table 8, VMT fees by household income group will be less incident on lower-income households than vehicle use fees.

Relationship to Efficiency

VMT fees encourage efficiency somewhat by pricing travel, although not applied to time of day or facility.

Ease of Implementation

VMT fees applied to all vehicles are not used anywhere, nor are they likely to be greeted warmly unless justified as part of a new approach and contract between the transportation agency and

TABLE 8 Shares of $10 Billion of Taxes Paid by Household, by Income Quintile and Source (*9,10*)

	Fuel Tax	Vehicle Sales Tax*	Vehicle Use Tax	VMT Tax
Quintile	($ billions)			
Bottom	0.944	0.622	1.111	0.922
Second	1.445	1.123	1.716	1.578
Third	2.027	1.821	2.060	2.043
Fourth	2.548	2.751	2.424	2.523
Highest	3.035	3.682	2.689	2.934
Total	10.000	10.000	10.000	10.000

NOTE: A quintile is one-fifth of the households. The bottom quintile is the group of households with the lowest income.

* A vehicle use tax based on value of the vehicle will be distributed approximately the same as a vehicle sales tax.

its customers. New administrative procedures would have to be developed. For states, adding on to their existing registration procedures provides a reasonable administrative approach.

A federal VMT fee that relies heavily on state enforcement is judged to be an unlikely eventuality. FHWA examined but rejected the possibility that the states would enforce a federal weight-distance tax (7). If, however, states themselves implement VMT fees, then a federal VMT fee will be enforced in parallel with state enforcement efforts, similar to the situation today with enhanced state-federal cooperation on fuel tax enforcement.

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Summaries of Panelists' Comments

Byron L. Geuy, *Western Highway Institute*

Byron Geuy complimented the authors on their analysis of changing economic structures and related implications for the transportation system, but he thought that much of the Roberts and Meyer paper seriously missed the mark.

Geuy noted that the last two major sections of the paper dealing with "trade-offs" discuss the needs of carriers and shippers versus the constraints of system capacity, providing examples of industrial efficiency—such as containerization and double stacks—that are outside the reach of legislators; thus no trade-off is involved, and an unduly rosy picture is created.

The authors again missed the point in describing system complexity and congestion as the barriers to the way of meeting shipping needs, according to Geuy. He said the real reason is political barriers fostered by the railroads that deliberately thwart competitors by increasing their costs any way they can.

Geuy described the authors' discussion of longer combination vehicles (LCVs) as plowing old ground superseded by industry policy and contemporary research that regard LCVs as an individual state or regional option under permit administration. The truth is, he said, LCVs are not experimental, having been in use since 1959, and are some of the safest trucks on the road. The authors should have looked at the Canadian B-train. With the threefold increase in trade prompted by the North American Free Trade Agreement, the United States cannot afford to be the weak link in the standards chain and must accommodate the proven and research-driven Canadian size and weight regime.

The authors were accused of drawing simplistic conclusions that discriminate against turnpike doubles, mandate expensive new hardware for triples, and totally ignore the most numerous LCVs. Finally, Geuy chastised the authors for using ton miles instead of dollars to measure transportation value added.

Geuy classified his comments on Reno's paper into three categories: the Good, the Bad, and the Ugly.

- The Good: The author's key point, "that the government agencies begin to view their investments and management actions as aimed at decreasing the costs of operating surface transportation or at increasing the productivity and competitiveness of the overall private sector, both firms and households."
- The Bad: The "new contract" between transportation agencies and customers that does not take into account people's frequent mistrust of bureaucrats, which increases proportionately with the distance from Washington.

• The Ugly: The author's discussion of vehicle miles of travel (VMT) fees discloses naivete toward mileage taxes, which are on their way out because they do not produce enough money, are evaded by taxpayers, are a deterrent to economic development programs, and are tailor-made for railroad promotion to target their long-haul competitors for special discriminatory tax treatment.

According to Geuy, the two-structure tax system, although not perfect, has served federal and state governments long and well; so "if it ain't broke, don't fix it," especially with a universal mileage tax.

Alan C. Courtney, *APL Stacktrain Services*

Alan Courtney commended the authors of the two papers for displaying a broad vision about the future of transportation. Courtney pointed out that private industry in the United States is currently reengineering itself to improve productivity and provide better goods and services on a global competitive scale. The reengineering process is part of a movement for global consciousness that includes increasing emphasis on teamwork and cooperation.

Courtney commented that by displaying their own visions of the future (particularly their approaches to infrastructure investment), the authors of both papers challenge their readers to develop new attitudes. Indeed, new attitudes are required not just to analyze the ideas presented in these papers but to realize the potential of a number of real-world situations. Courtney cited the "destructive" debate over LCVs as a case in point. Additionally, the new emphasis on intermodal transport requires that motor carriers and the highways they travel be viewed as part of a larger integrated system. The promise of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) and the National Highway System can be realized only through the development of creative new approaches and attitudes among transportation users, providers, policy makers, and administrators.

In conclusion, Courtney remarked that new technologies such as intelligent vehicle-highway systems have already arrived on the scene. It is imperative that symposium participants spread the word about the tremendous potential of these technologies. It is also imperative that participants exercise leadership by demonstrating new attitudes and a spirit of teamwork in addressing current and future issues in this field.

John W. Fuller, *University of Iowa*

The Roberts and Meyer paper paints a broad picture of change in trade, transportation, and U.S. distribution systems as international movements become increasingly central and important in the U.S. economy. Among the paper's many points either supporting the authors' thesis of change or suggesting steps to be taken because of internationalization pressures are the following:

• ISTEA stimulates system performance planning and the establishment of consistent nationwide performance measures or standards, and

• International trade corridors should be targeted and priority given to investments in these corridors.

Consistent highway performance is important to the nationwide just-in-time carrier because reliable highway service permits reliable deliveries. But national consistency in highways comes at a price—a price that highway agencies and politicians may be unable or unwilling to pay, especially if consistency means urban as well as rural consistency. Costs, priorities, and resources differ from place to place. John Fuller believes that operating knowledge of road throughput inconsistencies within the United States can substitute for consistency quite well in a real-world situation, permitting trucking reliability at lower cost.

Perhaps a better strategy would be to focus on targeting key bottlenecks to trade and invest in their elimination. Targeting bottlenecks is different from Roberts and Meyer's emphasis on investing in trade corridors. Bottlenecks are not just physical highway facilities and are more likely to emerge on both sides of the U.S. border than within the United States. This development may cause congestion in Canadian urban areas and deficiencies in Mexican intercity routes to become greater problems as trade expands. Achieving total trip reliability in international carriage may mean targeting investments outside the United States to address differences in interchange practices, regulatory philosophy, safety, and policing that may emerge to present reliability problems.

Is the United States ready to target corridors or practices that need improvement in other countries, in order to improve total transport or logistics costs and reliability for the entire movement? Interestingly, this attention to transportation problems in other countries as a way to improve U.S. international trade capabilities was suggested by Owen (*1*). The major challenge is to devise ways or mechanisms that effect needed investment. Perhaps we should investigate the use of public-private development groups or the prospects of cross-border joint developments of state departments of transportation with Canadian provinces and Mexican estados.

Turning to Reno's financing paper, Fuller was impressed by the review of federal and state user finance and the description of the pros and cons of different financing instruments. Reno's conclusion that financing tools have failed and the system has become "broken" is not, however, supportable. As can be seen by referencing other developed countries, we have a very high level of highway service in the United States. Financing tools have become more sophisticated and more integrated with developmental and other objectives. Tremendous local efforts have been directed toward funding roads and streets in this country, using local property taxes and other sources. Support for highways is moved by local development concerns and must be balanced against other local infrastructure needs. There has been an expanded use of impact fees and more private provision of local highways. These are exciting changes that prove the continued flexibility of today's financing system.

It is true that the United States has a large inventory of unmet highway needs, but Fuller questions the realism of the process used to generate these needs and doubts the political will to reduce the needs backlog in view of all the other demands that exist in society.

Reno makes an important observation that public highway costs are a small part of total highway user costs and that highway investment might lower overall costs substantially. We can substitute public capital for private operating, maintenance, and capital costs. Fuller agrees with this argument but points out that our political decision-making process simply does not support these rational trade-offs. It would take a metamorphosis to a highway marketplace to permit automobile or truck operators to choose the higher level of service that they wish to support—and such a sea change to markets is yet to come. Indeed, the change to transportation markets comes with its own threat to equity and to a mobile lifestyle.

Reno's focus on the benefits of more and better highway investment suggests a switch to benefits-based taxation in the United States, charging highway users in accord with the benefits that they receive from facility use; Reno advocates pollution emission fees as a benefits-related charge. Reno's paper does not detail how we could capture this consumers' surplus. Instead, he cited the Oregon State Transportation Plan as an example of a new benefits-based approach. Clearly a switch to benefits allocation and taxation, including pollution effects, marks a revolutionary change from today's system.

Before making such major changes, Fuller believes that it is appropriate to investigate Reno's Oregon example carefully. From Fuller's review of the Oregon plan and talks with Oregon's planners, he finds that a key missing part of that plan is an investment trade-off mechanism that would show whether one highway investment is economically superior to another, or that economic development related to a highway investment is more positive than environmental improvement related to investment in another mode. Net benefits are simply not easy to measure, or even to identify.

The actual tax instruments Reno cites for application under a benefits-based regime—VMT fees, congestion fees, pavement damage fees, in addition to all the current user fees devised over the past 80 years or so in the United States—certainly suggest the complex multitude of prospects available. Exactly how the rates are to be set, for whatever tax instruments are used, is less than clear. Are these rates somehow to equate users' benefits to the taxes paid? Will the rates be the same for each instrument, or do we rely on one more than another and in what circumstances? Are we going to further extend the support that transportation gives to the general fund, following the European example? Although the principles that Reno espouses may be commendable, the practice, in Fuller's opinion, is likely to become uncertain and mischievous.

In bringing together his observations on both the Reno paper and the Roberts and Meyer paper, Fuller returns to Owen's book and the concept of supporting transportation improvement by wise investment decisions, wherever the weakest link exists. Owen's financing instrument was simple: grants to remove bottlenecks among trading partners, based on their relative ability to pay. A fund would be generated using general, progressive tax instruments and the money applied wherever the net benefits to trade and society were the greatest. This approach suggests establishing a general capital account and writing the end to earmarked trust funds. This simple concept of investing where the returns are greatest, in the spirit of "win-win" trade situations across North American borders, would have the greatest practical impact in integrating the economies of these three societies in the decades to come. Perhaps such simplicity is the direction of the future, rather than the increased complexity of new, broad-based tax instruments, with concomitant fights among those taxed to minimize their fiscal impact. We do not want to lose sight of the larger gains to be achieved from trade.

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WORKSHOP SUMMARIES

Highway Systems To Facilitate Trade Needs and Funding for Productive Highways

Harry Caldwell, *Federal Highway Administration*
Paul O. Roberts, *Transmode Consultants, Inc.*

The concerns of this workshop's participants were elicited by Harry Caldwell, who oversees the preparation of a biennial U.S. Department of Transportation report to Congress and the White House on the status of the nation's highways, bridges, and transit. This report presents current highway characteristics and predicts the level of deterioration of pavement and operations as well as future performance characteristics (based on travel forecasts). The report does not, however, examine either the changing nature of the highway system or longer combination vehicles (LCVs) and other vehicle configurations—both of which are crucial to a meaningful discussion of future transportation needs.

Discussion

Participants pointed out that with the implementation of the North American Free Trade Agreement, there will be considerable pressure to rationalize weight limitations. States such as Texas will feel particular pressure to cope with heavier loads at the Mexican border. New taxation policies will be necessary to address the proliferation of heavier trucks.

It was further pointed out that most U.S. trucking has regional distribution. In the United States, the most common LCV is a double unit that hauls lumber, aggregates, and other heavy items. Of all combination-unit vehicles, 40 percent are tankers or flatbeds, not vans, and these units carry heavy loads for shorter distances. From a safety perspective, these are the most troublesome trucks. Participants stated that tax policy should focus on these types of trucks rather than on triples or turnpike double units.

It is crucial, some participants argued, to know (a) what kind of freight is moving in what kinds of trucks and (b) what happens to these and to the structure of the trucking industry if regulations are changed. In any case, it is shortsighted to base policy on 80,000-lb vehicles only.

Design standards for the 249 550-km (155,000-mi) National Highway System (NHS) must depend largely on how much money is available for maintenance, participants stated. Because the NHS is so large, without a clear understanding of the relative significance of different links and routes on the NHS, it lacks common system characteristics. Funds may be diluted across the system as a whole. In general, the NHS process has addressed mileage targets at the expense of freight needs, and participants cited this as a problem.

RECOMMENDATIONS

The question of highway system reliability, participants noted, is closely linked with the issue of congestion. Congestion levels in metropolitan areas are increasing, as are nonrecurring delays that traffic managers cannot forecast. Reliability must be promoted to accommodate new production methods, but mitigating congestion is extremely costly and difficult to accomplish by traditional means (e.g., lanes for vehicles with higher occupancies, bigger throughways, etc.). Several participants observed that the problem of congestion is unavoidably linked with other large problems—long commutes, metropolitan sprawl, and the decay of urban centers and associated pressure to keep industries downtown. Participants discussed the possibility of dedicated lanes (similar to high-occupancy vehicle lanes) for trucks as well as privately owned expressways; both of these options are politically problematic, however, because they raise the thorny question of who controls public rights of way (e.g., should private companies be able to charge whatever they want for travel on their own private roads?). Participants agreed that eventually commuters must allow certain roads to be dedicated, at certain hours, to commercial traffic entering congested metropolitan areas. Participants stressed that truck weight bears heavily on cost recovery. One participant noted that although pavement deterioration can be addressed through the use of additional axles, the major negative effects of heavier vehicles are on bridges, which could theoretically be improved selectively in known heavy-truck corridors. Participants reiterated that the weight issue is not an LCV issue; once again, the key questions concern the kinds of commodities being moved and the kinds of vehicles moving them, and these questions should drive NHS data-gathering studies and taxation policy. To make sound infrastructure investments, policy makers need to know about the workings of the market (now and in the future), vehicle configurations, and commodities. In short, a customer-driven needs analysis is urgently required instead of current efforts to define levels of service or to arrive at engineering solutions to transportation problems.

Although TRB has published a report on strategic data needs that addresses engineering, freight, and economic perspectives (*Special Report 234: Data for Decisions: Requirements for National Transportation Policy Making*), there is still no clear understanding of how to obtain the needed data. Participants recommended that brief, regular studies of commodity flows (and their ramifications for vehicle configuration) be conducted. These studies can and should make use of evolving smart technologies but should not necessarily be ongoing, institutionalized data-collection efforts. The problem with the latter, said some participants, is that they become ponderous; small, focused, regular studies would probably be more efficacious.

Economic, Environmental, and Energy Impacts of Trucks in Metropolitan Areas

Gary E. Maring, *Federal Highway Administration*

Gary Maring introduced the workshop topic and charge to the group. He emphasized that freight movement is vital to the economic well-being of metropolitan areas. Trucks carry a large share of the freight moved in metropolitan areas. They bring in raw materials and processed goods for manufacturing, distribute finished goods to warehouses and consumer outlets, and make deliveries to consumers and businesses. Trucks move goods to and from air and sea ports as well as rail and river terminals. Efficient truck operations reduce the costs for doing business. Inefficient truck operations not only increase business costs but delay other traffic, contribute to air pollution, and waste fuel. In particular, urban traffic congestion, by causing truck delays, increases truck operating costs and delays deliveries. Trucks making deliveries can cause traffic congestion, especially when stopped in a traffic lane during loading or unloading.

States and metropolitan planning organizations (MPOs) need to address these freight problems as part of the Clean Air Act and the planning requirements of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) and in congestion and intermodal management systems. Freight is identified as one of the key issues to be addressed in the planning process. But before solutions can be evaluated fully, the roles that shippers and carriers play in the economic activity of the metropolitan area need to be better understood.

Obtaining the needed input requires shippers and carriers to be involved in the metropolitan planning process. This input would help identify trucking and intermodal freight improvement needs and evaluate strategies for reducing urban traffic congestion and emissions, to ensure that there is not an undue impact on regional, interstate, and international freight movement. Some initial recommendations were developed at a conference in New Orleans, Louisiana, last fall entitled "Trucking, MPOs, and Urban Highway Planning." Mechanisms for involving these interests in the state and local transportation planning processes and technical issues such as existing planning tools for freight were discussed.

The purpose of this workshop was to determine what research or policy direction is needed in the areas of industry involvement, freight planning tools, congestion reduction, and environmental and energy impacts of truck freight movement.

Discussion

After participants introduced themselves, Maring asked them to identify key issues from their perspectives. The following were identified:

- Data and cultural gaps exist among planners and the truck freight industry.
- Freight bottlenecks need to be identified.
- Staffing resources at the local level are inadequate for freight planning.
- A freight planning manual such as the previous passenger-oriented Characteristics of Urban Transportation Systems (CUTS) should be developed.
- There appears to be a lack of knowledge and methodology for analyzing the emissions of heavy trucks, and speed data for trucks are not readily available.
- Partnerships between industry and MPOs are needed.
- Congestion management plans need to consider freight.
- Reduction in commercial parking space is a problem for delivery, and enforcement is a problem.
- Economic planning and development issues need to be brought to the forefront of the planning process.
- A lack of education on freight transportation exists among transportation planners; an action plan would be to develop a change or addition to the curriculum at colleges (e.g., the Association for Collegiate Schools of Planning) or to institute training courses and funded chairs.
- Industry outreach and liaison with public officials is needed.
- Opportunities for freight operational and capital investments must be identified. With flexible funding under ISTEA, freight interests must more actively pursue needed improvements.
- Building codes or zoning regulations do not adequately consider the need for loading and unloading docks.
- Intelligent vehicle-highway system applications to urban freight problems should be investigated and could provide great benefits, including identification of trucking restrictions (e.g., restrictions for trucks carrying hazardous materials, bridge height limitations).

Recommendations

Maring then asked the participants to identify three or four of the most critical issues that should be highlighted for early attention. Following is a summary of those issues with some suggested strategies:

- Need for partnerships. Both governmental and industry (shipper and carrier) interests need to take the initiative to ensure that freight issues are adequately represented in statewide and metropolitan plans, programs, and management systems. Specific examples mentioned included (a) United Parcel Service's initiative to contact key local officials in major metropolitan areas, seeking involvement in the process, raising key issues, and offering assistance in resolving them; and (b) MPOs involving shipper representatives through membership on advisory or technical committees dealing with freight issues.
- Information, data on freight. State and local planning agencies need to better understand industry, shipper, carrier distribution, and logistics processes. Initial meetings of transportation planners and industry representatives have shown a "cultural gap" regarding terminology, perspectives on critical issues, time frames, and so on. Sustained involvement, information sharing, and data development will be necessary to overcome such barriers.

One specific data need mentioned was commodity flow information. One possible source is the Nationwide Commodity Flow Survey being conducted by the Bureau of the Census. The use of these data to provide at least international and interstate flows for state and local governments should be pursued.

Another data need identified was air pollutant emission rates for heavy trucks. Idling and speed data are inadequate to provide accurate emissions estimates.

- Bottleneck or opportunity analysis. Rather than initially undertaking a large freight systems analysis and modeling effort, the group agreed that it would be best to pursue a bottleneck appraisal. Critical points in the transportation system that affect freight—such as

intermodal terminals, major truck terminals, interchanges, heavy congestion points on freight routes, and incident locations—should be identified. This approach was emphasized in order to get freight projects identified early so that they can compete for funding in the planning and programming process. The ISTEA funding is more flexible, bringing more interests to the table. Freight interests must be fully considered in this process.

- Education. The group believed that state and local transportation planners had inadequate training in freight matters. Three remedial strategies were suggested:
  - –University curricula for transportation planners should include freight transportation elements. Interdisciplinary approaches with transportation business or economic schools are one possibility. Another, suggested by John Fuller from the University of Iowa, was to involve the National Association for Collegiate Schools of Planning and include this issue on their national meeting agenda.
  - –To train current state and local transportation planners, it was suggested that FHWA, through the National Highway Institute, offer training in this area.
  - –It was also suggested that a technical guide or manual on freight transportation for state and local transportation planners be prepared.

Highway Cost Responsibility and Allocation

Joseph R. Stowers, *SYDEC, Inc.*

Joseph Stowers offered a list of issues and common themes that had been raised throughout the symposium. A lively discussion on their relevance to or impact on highway cost responsibility and allocation ensued.

Discussion and Recommendations

- *Is a benefits-based tax system viable? What effect would it have on the tax structure or motor carrier taxes?*

  –Avoid major changes in tax mechanisms because the public wants certainty in them.

  –Marginal and benefits pricing are good concepts, but data for either are inadequate. A cost-occasioned system of cost allocation has achieved greater acceptance, and data for it are more readily available.

  –Benefits-based investments do not require benefits-based cost allocations, although the latter do eliminate difficulties in allocating common costs. Benefits-based calculation methods and their data requirements are not adequately defined and present some unresolved problems.

- *If an LCV system is enacted, what mechanisms can be used to ensure that cost responsibility is covered?*

  –Require states to do cost allocations before allowing them to have LCVs.

  –Before establishing an LCV network, there must be assurances made that LCVs are meeting current cost responsibilities and that permit fees recover full cost responsibility.

  –An LCV tax could involve additional pavement costs but might include other, harder to measure costs. It may be difficult for an LCV permitting system to assign the additional costs. (Interchange geometrics exemplify this kind of cost.) A high portion of the interchange costs should be considered to be the cost responsibility of large trucks.

- *What research is most needed to improve the quality and validity of cost allocation studies?*

  –Vehicle mile distribution by vehicle type, pavement damage models, bridge damage models, and all inputs into cost allocation need to be improved.

–Vehicle features that help minimize damage to roads but add to vehicle weight should be examined and encouraged to the extent warranted. Carriers should not be penalized through reduced vehicle payloads for adding features that minimize infrastructure damage.

• *Can reliance on fuel taxes provide satisfactory payment of cost responsibility, using surcharges in fuel use reporting?*

–Because newer, more fuel-efficient trucks pay lower taxes per mile than older trucks, this reliance would favor fleets with newer trucks. However, a tax related to axle weights and miles traveled avoids fuel tax bias in favor of newer trucks.

–Consider a graduated tax associated with fuel tax reporting on miles per gallon and intrastate miles traveled. When reports are filed, a tax surcharge could be based on vehicle weights.

• *Is the purpose of pricing to pay costs or to achieve other goals, such as reducing congestion, fuel consumption, or emissions?*

–Two tiers of pricing are needed. The first tier would recover public-sector costs in providing infrastructure. The second would recover the other kinds of costs.

–There was consensus that taxes to minimize congestion or reduce pollution were justified, as long as infrastructure costs were recovered through more traditional taxes.

APPENDIX—*Special Presentation*

Innovative and Productive Vehicle Combinations in Australia: A Performance-Based Approach

Peter F. Sweatman, *Road User Research Pty. Ltd., Australia*

A slide presentation allowed participants to see how Australia has uniquely applied performance measures to accommodate its special motor carrier needs. Trucking in Australia involves long distances driven over varying road conditions, so many vehicle combinations have been considered.

Australia has three vehicle classes:

1. As of right (or general access) vehicles, which are mainly six-axle tractor-semitrailers and some truck-trailers that can be up to 42.5 tons gross combination mass (GCM) and 19 m (62 ft) long;
2. Medium combination (or route permit) vehicles (MCVs), which are mainly B-doubles and some heavy truck-trailers that can be up to 59 tons GCM and 23 m (75 ft) long; they generally perform as well as or better than general access vehicles; and
3. Road trains, which operate in certain areas, are usually doubles or triples and are beginning to employ innovative combinations of B-trailers. Type 1 road trains are limited to 79 tons and 36 m (118 ft); Type 2 trains are limited to 116 tons and 52 m (171 ft). Although road trains have been used for a long time, their performance is inferior to general access vehicles or MCVs.

To judge vehicle performance, Australian authorities may consider rollover stability, rearward amplification, low-speed offtracking, high-speed offtracking, and swept width (the amount of sway that a long combination has as it travels a roadway). Virtually all possible vehicle configurations are being considered in performance and evaluations.

Initial performance evaluations found the best configurations to be B-doubles, B-triples, B-quads, AB-triples, and BAB-quads; the worst configuration for performance was the A-triple. These tests also determined that triaxles improve performance. From a productivity point of view, length limits constrain use, but shorter semitrailers (12.5 m, or 41 ft) improve flexibility and productivity in fleets covering all vehicle classes. B-doubles, B-triples, AB-triples, and BAB-quads offer high utilization and productivity across all vehicle classes.

Concluding his remarks, Peter Sweatman said that performance standards should be relative to vehicle configuration and, if established in place of conventional size and weight regulations, allow productivity gains (such as more weight on larger vehicles or more cube through more access). Furthermore, standards should be established with an eye on safety improvement (i.e.,

providing better stability and tracking) and on the potential for reducing the number of trucks required for the transportation task.

Questions and Answers

- *Would Australia allow Canadian C-dollies to be used on its vehicles?*

Sweatman said that no decision had been made. There are Canadian standards but no significant industry demand for C-dollies, and practical difficulties exist for Australian fleets.

- *What are the benefits of a sign, seen in one of the slides, that cautioned drivers that B-doubles are "long vehicles?"*

Sweatman replied that he didn't think those signs, part of government requirements, made any difference.

- *Are triaxles steerable?*

Sweatman said that they are not but that the Australian bridge community has supported wider spacing on triaxle vehicles, and that a package is being developed. This may increase the need for steerable axles, but he surmised that such spacings would probably be manageable with a fixed axle.

- *How did the Thomas tanker, seen in some slides, evolve?*

Sweatman explained that Shell Oil and Hockney looked at various tanker-truck concepts being used around the world and tried to design a truck that would surpass all of them, with roll stability being a major design criterion. The Thomas tanker evolved and, although not many are in use, these trucks are doing well in the transportation of hazardous materials.

- *What is the Australian truck use tax structure?*

Sweatman and Pearson said that, in Australian dollars, the rates are $0.29/L for federal excise tax, up to $0.06/L for various state taxes, and $7,000 to $12,000 for annual charges. He noted that dramatic increases in road train charges have been proposed but face strong regional opposition.

Acknowledgments

The symposium steering committee acknowledges many individuals and organizations that helped make the symposium a success. Peter Griskivich, retired vice president, American Automobile Manufacturers Association (AAMA), guided the development of the symposium in several roles: first as chairman of the program subcommittee of the TRB Committee on Motor Vehicle Size and Weight, later as a consultant to TRB, and finally as the presiding officer at the opening and closing plenary sessions. Peter was instrumental in bringing together the resources of organizations, both national and international, in developing the symposium program. Carole Guzzetta, formerly of AAMA, provided valuable assistance in the early stages of organizing the symposium.

The steering committee also wishes to recognize the contributions of the liaison representatives—Douglas J. McKelvey and Susan J. Binder, FHWA; Robert M. Clarke, NHTSA; and Linda Bauer Darr, American Trucking Associations—in developing the program and conducting the symposium. Special recognition is also given to Philip W. Blow, FHWA, for his handling of administrative activities, which played a large role in the symposium's success.

In addition, Jeffrey Loftus, FHWA, coordinated the Student Paper Competition, a national competition open to transportation students in more than 60 colleges and universities. Contestants selected topics related to the symposium subject areas. The co-winners, Claudia Said and Amelia Regan, both students from the University of Texas, provided student observations as part of the closing plenary session.

The following cooperating organizations also supported the symposium:

- American Association of State Highway and Transportation Officials,
- American Trucking Associations,
- Canadian Trucking Association,
- Commercial Vehicle Safety Alliance,
- Intermodal Association of North America,
- International Road Federation,
- International Road Transport Union,
- National Private Truck Council,
- Society of Automotive Engineers,
- Transportation Association of Canada,
- Transport Canada,

- Truck Trailer Manufacturers Association, and
- Western Highway Institute.

The steering committee also thanks all those individuals who participated in the symposium: the session leaders and secretaries, workshop leaders, speakers, panelists, paper authors, paper reviewers, and those who attended the conference and contributed to the output of the workshops.

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The following acronyms are used without definitions:

AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials (formerly AASHO)
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
IEEE	Institute of Electrical and Electronics Engineers
ITE	Institute of Transportation Engineers
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
SAE	Society of Automotive Engineers
TCRP	Transit Cooperative Research Program
TRB	Transportation Research Board

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