Review of the U.S. Freight System: Possibilities for the Future: Phase II Report (1980)

Pages
62

Size
8.5 x 10

ISBN
0309340934

Committee on Transportation; Assembly of Engineering; National Research Council

959203 PB83-145722

A Review of the U.S. Freight System: Possibilities for the Future

(Phase 2 rept)

National Research Council, Washington, DC.

Corp. Source Codes: 019026000

Sponsor: Department of Transportation, Washington, DC.

1980 60p

Languages: English

NTIS Prices: PC A04/MF A01

Country of Publication: United States

Journal Announcement: GRAI8308

Contract No.: DOT-OS-70001; DOT-RC-92002

The Committee on Transportation of the National Research Council, Assembly of Engineering, examined existing forecasts to refine and bring them up to date and considered the research and development that would lead to their improvement. The proceedings (Forecast of Freight System Demand and Related Research Needs) were published in 1979. As the committee proceeded through Phase II of the study, the consensus developed that three key issues encompassed the multiplicity of difficulties distributed throughout the freight system. They are: (1) role of government, (2) roles of technology, and (3) information analysis and assessment capabilities. The present report has, therefore, been constructed around these three issues.

Descriptors: *Cargo transportation; *United States; Evaluation; Demand(Economics); Forecasting; Technology; Government policies; Information systems; Data processing

Section Headings: 13B (Mechanical, Industrial, Civil, and Marine Engineering--Civil Engineering); 91B (Urban and Regional Technology and Development--Transportation and Traffic Planning); 85GE (Transportation--General)

A Review of the U.S. Freight System: Possibilities for the Future

PHASE II REPORT

Committee on Transportation
Assembly of Engineering
National Research Council

NATIONAL ACADEMY PRESS
Washington, D.C. 1980

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This report has been reviewed by a group other than the authors, according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

This is a report of work supported by Contracts No. DOT-OS-70001 and No. DOT-RC-92002, between the Department of Transportation and the National Academy of Sciences.

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PREFACE

The Committee on Transportation of the National Research Council, Assembly of Engineering, has conducted a review of the nation's freight system for the U.S. Department of Transportation (DOT). The study was accomplished in two phases. The first, described in A Review of the U.S. Freight System, Phase I Report, Possibilities for the Future, discussed the major issues and made a preliminary evaluation of the potential for improvement in the freight transportation system over the next 25 years through technological and institutional changes. The U.S. freight system as defined for this study deals principally with the intercity portion of the total system, including air, motor carrier, rail, waterway and pipeline. International freight is not a primary concern. The principal objectives of the second phase were to identify the major fundamental problems that must be overcome to realize the system's potential for improvement and to recommend research and development programs that would contribute to the resolution of these problems. Among the many institutional matters considered in Phase I of this study, the need for change in existing economic and safety regulation was given particular attention. The committee conducted a workshop on the economic regulation of motor carriers to explore this subject in detail. The National Research Council published the proceedings (Motor Carrier Economic Regulation) in 1978.

Early in the Phase II effort, the committee studied forecasts of demand for the shipment of goods and commodities over the next 20 years. The committee, through a workshop, examined existing forecasts to refine and bring them up to date and considered the research and development that would lead to their improvement. The proceedings (Forecast of Freight System Demand and Related Research Needs) were published in 1979.

As outlined in the committee's Phase I report, freight transportation provides essential services to society. However, the viability of some elements of the for-hire sector of our national freight system is threatened by serious problems. Some of the carriers providing for-hire services to anyone wishing to ship goods encounter severe financial constraints. The financial burden of maintaining the extensive publicly owned infrastructure is growing faster than revenues. Some observers warn that the system is not adapting to changing conditions as rapidly as it should and will have even greater problems in the future. In its Phase I report, the committee identified a number of important issues. These are: how to

improve the process of technological evolution, how to improve government participation, what evaluation criteria are best for determining the extent of this participation, how best to create incentives to improve productivity, and how to improve the freight demand forecasting capabilities. For the reader without ready access to the Phase I report, additional explanation of these issues and a brief overview of the committee's conclusions are given in Appendix A.

As the committee proceeded through Phase II of the study, the consensus developed that three key issues encompassed the multiplicity of difficulties distributed throughout the freight system. They are: (1) role of government, (2) roles of technology, and (3) information analysis and assessment capabilities. The present report has, therefore, been constructed around these three issues.

The committee wishes to express its appreciation to DOT, to officials of the Canadian transportation companies, Canadian National and Canadian Pacific, Inc., and to the officials of the European and Japanese transportation agencies with whom we consulted. Appreciation is also expressed for the participation of the many leaders of the transportation community who presented or discussed material during the study. These individuals are listed in Appendix B, ACKNOWLEDGMENTS.

The committee expresses special appreciation for the many contributions made during this and previous studies by Dr. James R. Nelson, who died April 30th, 1980.

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SUMMARY

It is the committee's perception that the railroad system is more seriously constrained by both institutional and technical problems than are other modes of transportation. The government has already taken several actions to alleviate these problems, which will provide experience concerning the effectiveness of federal assistance (e.g., establishment of the U.S. Railway Association, CONRAIL, and AMTRAK). Because of this perception, the committee tended to focus on railroad problems, guided by the conviction that other modes will eventually face many of the same problems if corrective steps are not taken to resolve them. However, the committee's recommendations clearly relate to improvements of the overall freight system, cover both short- and long-range activities, and emphasize efforts that deserve high priority. The primary aim is to provide useful suggestions to DOT to assist them in improving the overall freight network by encouraging the most efficient and appropriate use of each mode, and by stimulating more efficient combinations of modes. Further definition of the system and examples of this approach are in the introduction and subsequent chapters.

As mentioned previously, the discussions and recommendations are grouped in three categories where there are serious problems and where actions are needed to bring about improvement.

(1) The Role of Government: After discussion of the traditional and emerging roles of the government in the provision of freight transport, the committee concludes that the government can influence the development of the transportation system in two ways: by providing facilities and services directly and by providing the framework within which other entities can furnish transportation.

The committee believes that there are a number of actions or activities that the government could undertake, sponsor, or encourage which would improve the freight system. Some are research, and some are more in the nature of analysis and program development. Before listing these, the committee offers one major suggestion that it believes will significantly influence the role that government, particularly the DOT, can perform.

The many problems facing the freight transportation system, in most cases, involve institutional as well as technical matters. Although there is not one single agency to deal with the problems--the departments of Transportation, Energy, Commerce, Housing and Urban Development; regulatory agencies; Congress; the courts; and others all play a part--one agency could become the focal point and management

agency for action to solve them. The committee believes that could and should be DOT. Although more detail is given on what such a lead agency organization should do in the chapters on roles of government and technology, as well as under analysis and assessment, an overall outline of this suggestion is given here.

The committee suggests that the DOT consider establishing, on a permanent basis in the Office of the Secretary, a national freight system planning and programming activity. The active participation of the other government agencies, as well as that of providers and users of freight transportation, would be vital.

The objectives would be to analyze the critical problems of the overall system and to develop and keep current a continuing plan of coordinated action to solve these problems. The activity would deal with institutional and technical problems and systems analyses. It would coordinate research, development, demonstration, testing, evaluation programs, and funding.

The committee believes that such a concentrated attack on system problems, as opposed to the intermittent attention they now receive from various organizations scattered throughout the DOT, is needed to bring about the improvements for which there is potential but no positive direction.

To return to the research and analysis efforts, the committee recommends that:

(a) attention be given to research and development that could help in deciding on arrangements for improving freight system productivity. The efforts should include studies to improve capital and labor productivity, to compare labor productivity, to compare labor in the several modes, to consider merger and consolidation policy, and to promote standardization;

(b) a broad-scale analysis of the freight system regulatory processes be made for all modes. The analysis should provide for representation of all points of view and for objectivity and should be conducted under the auspices of the joint activity described above, made up of representatives from pertinent government agencies, industry, and labor. Both economic and safety regulatory matters should be included in the analysis;

(c) alternative plans for reorganizing the national rail network be evaluated. The study should look further into the future than have previous studies and consider regulatory reform as well as capital needs; and

(d) the organization of a national freight system planning and programming activity within the Department of Transportation, suggested above, give priority to maximizing the effectiveness of operations by using the most efficient modes for particular movements (e.g., bulk freight by barge or rail, high value, small shipments by truck or air).

(2) Roles of Technology: The committee believes that in addition to innovation and change in the institutional aspects of the conduct of freight transport, technological improvements are also necessary. A distinction is made between research dealing with components of a modal system and research dealing with the way various components are matched and operated together as a system to meet market demands.

There are significant opportunities for the application of existing and new technology to improve the freight transportation system. Examples include potential improvements to system productivity and economic efficiency, to safety, and to the conservation of oil, in particular, and also of other energy sources.

The committee, therefore, recommends an increase in research and development efforts along two coordinated lines, as follows:

(a) introduction of policy and legislative initiatives (particularly those in regulatory areas) that would provide incentives for freight system carriers, shippers, and suppliers in the development and application of new technology and technological innovation aimed at improving productivity, safety, and the more efficient use and conservation of energy; and

(b) initiation of an expanded freight system research and development program by DOT with the following key elements:

- support for development of new technology as well as for better application of existing technology;
- work on overall systems to improve intermodal capability and network efficiency as well as on improving components such as: guidance devices for air and marine use, and improvements to propulsion efficiency for all modes;
- encouragement of technological innovation to include radio dispatched flexible routing and scheduling in freight pick up and delivery services; and
- provision of opportunities for carriers, suppliers, shippers, labor, universities, and others to participate in the program.

(3) Information, Analysis, and Assessment Capability: The committee stresses the importance of an assessment capability adequate to provide the insights needed for future transport decisions, including the ways in which an adequate assessment process can serve the department's decision-making role. Improvement is needed in data collection and processing. This does not imply a massive new effort, but rather greater selectivity and efficiency. More extensive use of sampling and behavioral models could be helpful to decision makers. New computer techniques can be applied to the storing of disaggregated data and generation of specific results when needed. Such disaggregated data as those from the ICC's One Percent Rail Waybill Survey, the Federal Highway Administration's Truck Use Survey, and

other surveys, may be used to estimate total tons or ton miles shipped when aggregated, or when samples are totalled for the purpose of covering all modes. (See pp. 128-132, NAS, 1979a, for further detail.) The confidentiality restrictions on the use of data in disaggregated form must be changed to permit greater use of such information by policymakers.

The committee concludes that current methods of gathering, storing, and using data, as well as present modeling practices, are inefficient. As is noted in more detail in the last chapter, transportation data collection and handling is a massive and complex undertaking. Data of many kinds are collected through the Census of Transportation; by the regulatory agencies; by the highway, rail, air, and water systems; by the Postal Service; by the Corps of Engineers; etc. Freight movement in one way or another affects everyone, and the problem of getting needed data in usable form is very difficult to solve.

DOT needs to create an information gathering and analysis function that puts the information available from the many government agencies into a useful form and which also seeks to gather other needed information to define the real performance of the U.S. freight system and its individual elements.

Research is needed to develop better methods of forecasting future freight movement and to establish an improved information, analysis, and assessment capability.

Toward this end, the committee recommends a number of approaches, including:

(a) stressing the use of disaggregated data sets, with emphasis on careful sampling of data rather than mass accumulation of freight data, designed to minimize confidentiality restrictions so that the information can be used by government and the private sector;
(b) initiating a series of pilot applications and case studies to assist in improving use of the data in the description, formulation, evaluation, and assessment process mentioned above, and in posing the inquiries and special data collection efforts that need to be undertaken; and
(c) supporting the development of new methodology on a consistent basis over time, even if at a modest level.

INTRODUCTION

Freight transportation provides essential services to society, and the freight system is a complex collection of carriers which moves a broad range of commodities over an extensive geographical network. The U.S. freight system as treated in this report is defined as that part of the total system serving the continental states, plus Alaska and Hawaii. This report deals primarily with the intercity portion of the system in all its modes--air, ground (truck, rail), waterway, and pipeline. The vehicles and equipment as well as the infrastructure, (i.e, tracks, highways, waterways, etc.) are considered. Except to note that the port and international freight movement must grow to accommodate increased freight movement, and is estimated to grow at about the same rate as the GNP, the report does not give the international movement detailed attention. The committee believes that, except for spot problems, that part of the system can handle the growth. Our nation has a sizeable investment in the present system and faces large replacement costs as well as steadily escalating maintenance costs.

There is a consensus that there will be a relatively steady growth in the transportation of most of the types of goods we now ship. In the committee's Phase I report (NAS, 1979a, pp. 32, 89-97) forecasts of the growth of the GNP, the population, and the demand for freight shipment are summarized and discussed. For example, a medium-growth assumption for the period 1975 to 2000 showed the population increasing some 22 percent to 260 million, the labor force increasing 37 percent to 137 million, and the GNP increasing about 85 percent to $2.77 trillion/year (expressed in 1972 dollars). Since historically, in the aggregate, freight movement in ton-miles has grown at about the same rate as the GNP, the general assumption was made, as in DOT's report, Trends and Choices, and others, that such a relation would continue from now until the year 2000 (DOT, 1977b).

Phase II of this study included a special workshop on forecasting freight demand (NAS, 1979b) and additional interaction with freight carriers and users of the various modes. As a result of these activities, the earlier estimates were refined. These later estimates are included here to give some idea of the timing and magnitude of growth in freight movement which can be expected over the next 20 to 25 years (DOT, 1976a; DOT, 1977a).

Klein and Loxley (NAS, 1979b), from the results of the Wharton Annual Model, estimate that the GNP will grow from now until 1995 at the average rate of about 3 percent a year, with growth of overall

ton-miles shipped of about 3.1 percent. (For an estimate of the year-by-year growth in GNP and freight ton-miles, see Figure 1; for growth of ton-miles shipped by various modes, see Figures 2 and 3.)

To state these estimates in terms of dollars and ton-miles, by 2000 the GNP will more than double, increasing 109 percent to about $3.17 trillion (1975 dollars), and the freight ton-miles between 1975 and 2000 will be up some 114 percent to about 5.23 trillion ton-miles (Department of Commerce, 1977; NAS, 1979b).

The dimensions of the task facing the future U.S. freight system are large. As shown in Table 1, the growth of shipment of some commodities is expected to be quite different from that of others, thereby posing transitional difficulties. For example, the shipment of metallic minerals is forecasted to grow 6.4 percent annually between 1973 and 1995, while the shipment of primary metal products is forecasted to grow only 1.8 percent per year. Table 1 lists the historical and projected rates of growth in shipments of 26 commodities.

Note that the growth rate of tons shipped is expected to increase from its 1957-1973 value of 2.4 percent per year to 3 percent per year during 1973-1995. The increase is attributed to the expected significant increases in the growth rate of tons shipped for manufactured metal products, coal, crude petroleum, and gas.

From the extensive list of critical problems identified in the Phase I report, the committee selected eight for renewed emphasis in the present report. The eight problems selected are considered fundamental to achieving improvements in the freight systems, to be of a continuing nature and, therefore, requiring actions that are long-term. The committee believes these problems should be addressed by government as a whole and DOT in particular, but in close cooperation with the private sector. They are:

1. Knowledge by government of the relative effectiveness and potential productivity of the various modes in handling different classes of commodities is now inadequate. Such knowledge is essential in providing for effective allocation of limited public resources. For example, information concerning the relative effectiveness in handling various types of freight permits decision on how the several modes may be used most efficiently and economically for such services.

2. There is a lack of incentives for productivity improvement. Management and labor have few incentives to work toward this end. Institutional restraints of various kinds are perceived to discourage technological innovation and limit the productivity of capital stock and labor.

3. Some components of the existing regulatory structure, which are unrelated to current economic realities, appear to impose unnecessary burdens on carriers. The problem exists with both economic and safety regulatory structures and involves tradeoffs with respect to such matters as safety, social welfare, environmental concerns, and cost effectiveness.

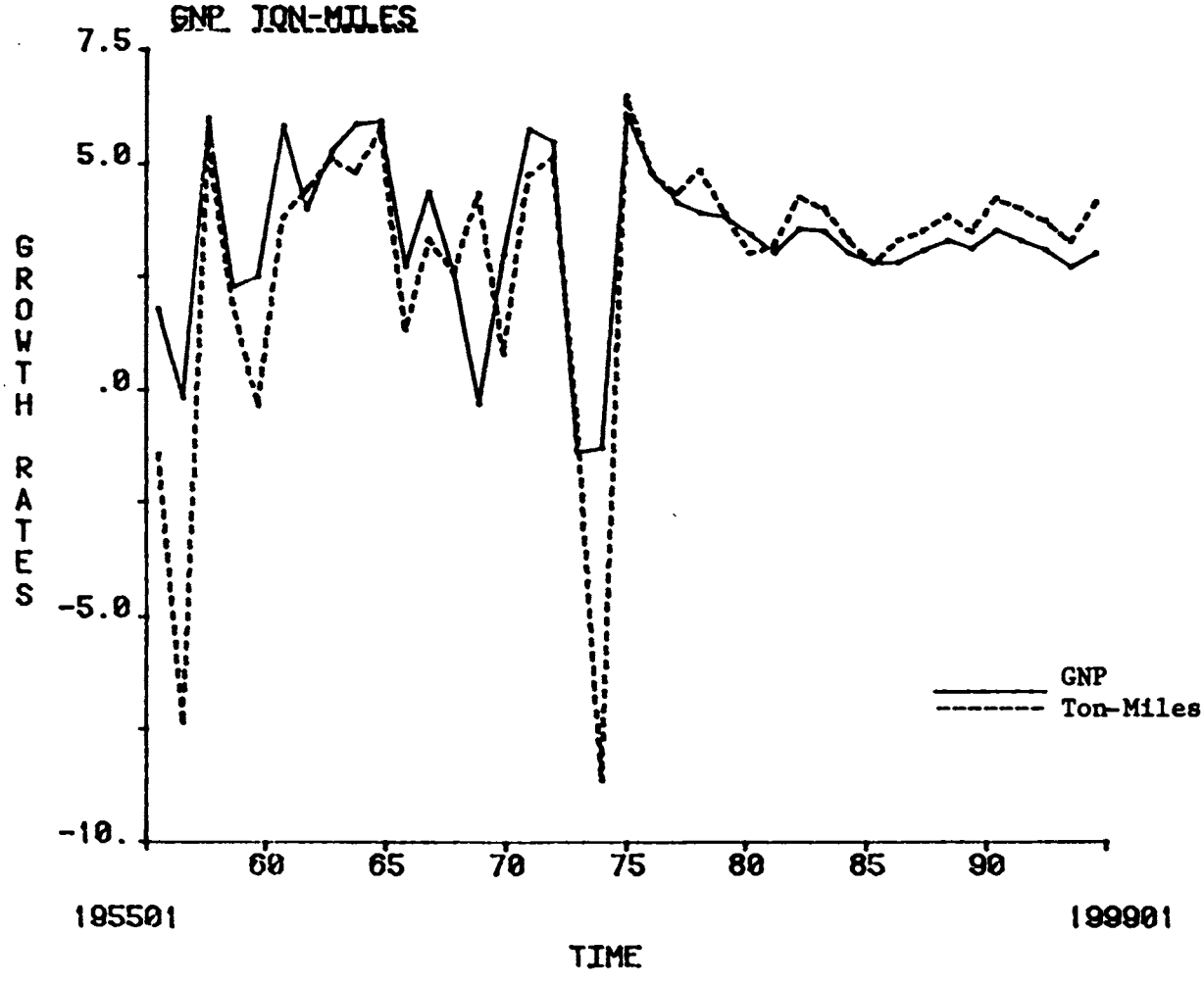


FIGURE 1 The economy and transportation growth rates, 1957-95.
Source: R. Epstein, et al. The Demand for Transportation. Wharton EFA, Inc., June 1978

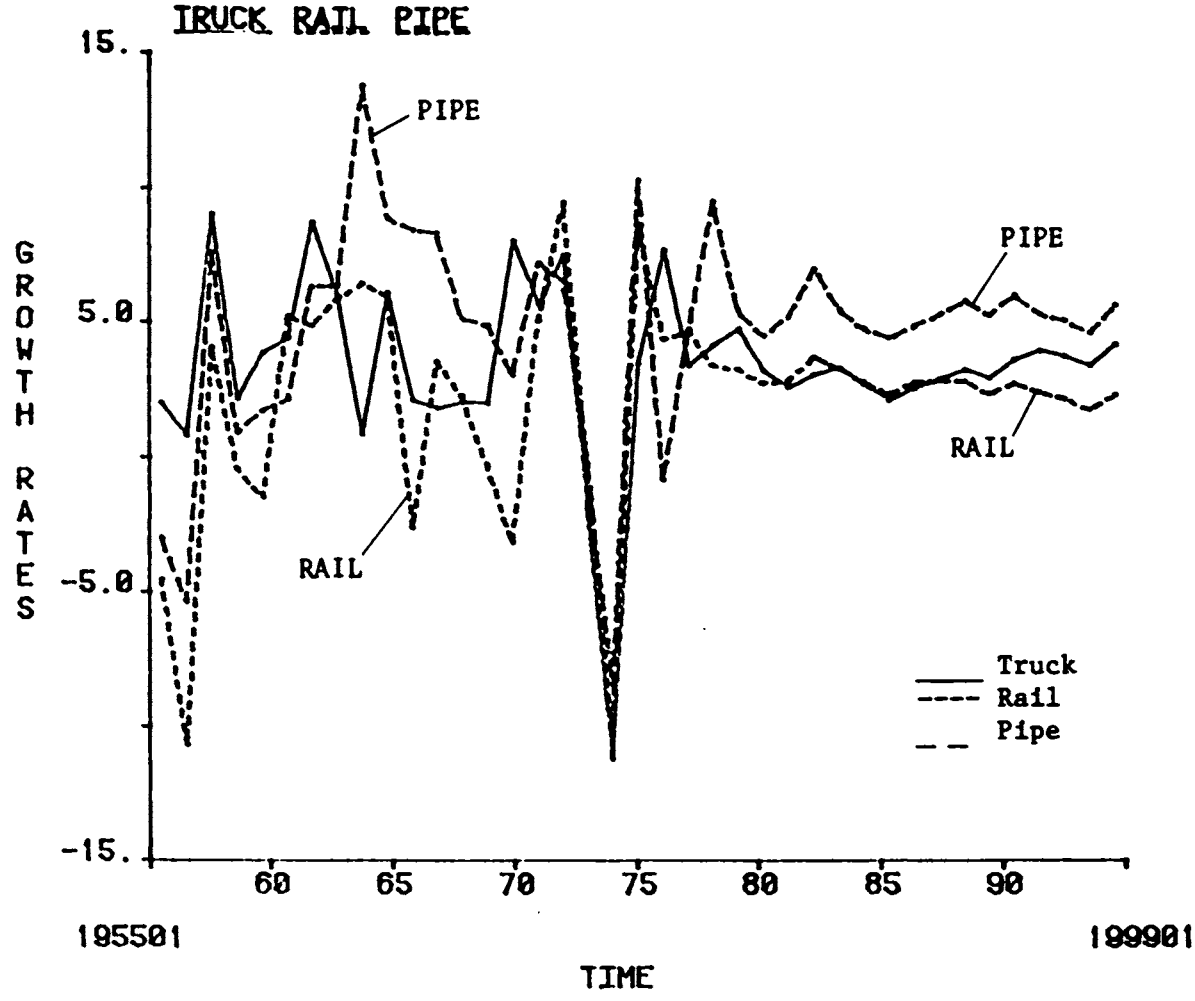
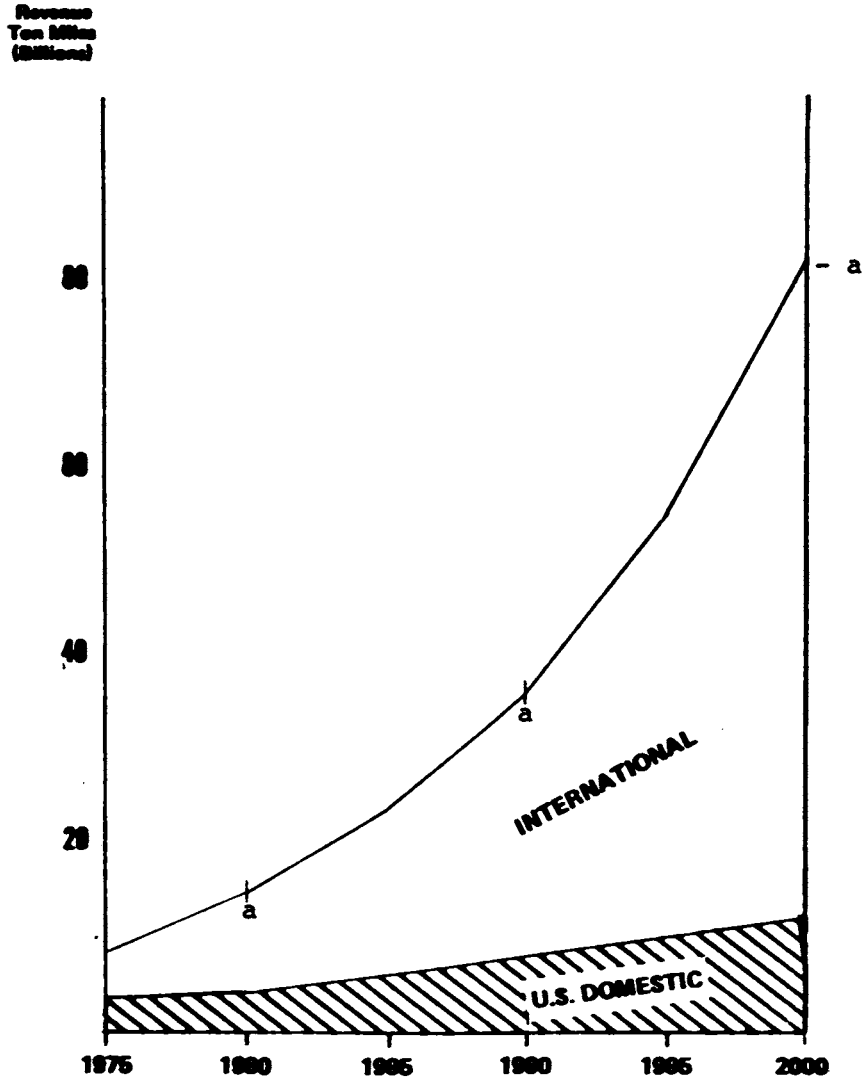


FIGURE 2 Ton-miles shipped and growth rates, 1957-95.
Source: R. Epstein, et al. The Demand for Transportation. Wharton EFA, Inc., June 1978



	International	Domestic
Average Annual Growth	10.7%	5.3%

a. Average growth of international ton-miles, 1980 to 1990 is about 11%; from 1990 to 2000, about 10% per year. Domestic freight growth, as noted, 5.3% per year.

FIGURE 3 U.S. related world cargo, domestic vs. international revenue ton-miles (billions) (air transportation)
Source: Domestic and International United States Connected Cargo Forecast 1975-2000 Summary. Air Transport Association of America, 1978.

TABLE 1 Output and Tons Shipped--Growth Rates

	Historical, 1957-73		Projected, 1973-95	
Sector	Output (%)	Tons (%)	Output (%)	Tons (%)
GNP	3.8	2.4 (Total)	3.0	3.0 (Total)
Manufacturing, minerals, and agriculture	3.5	2.4 (Total)	3.3	3.0 (Total)
All manufacturing	4.0	3.6	3.3	3.1
Agriculture	1.0	0.8	2.3	0.5
Metallic minerals	1.5	-0.7	6.4	1.9
Coal	0.6	-0.3	3.5	4.1
Crude petroleum and gas	1.8	1.8	4.5	3.5
Nonmetallic minerals	2.8	0.5	3.0	2.9
Food	2.5	3.2	3.3	4.0
Tobacco	2.6	3.4	3.1	5.4
Textiles	5.0	5.4	2.7	2.2
Apparel	4.0	8.5	3.3	7.4
Lumber	4.6	2.5	3.6	1.6
Furniture	3.8	6.1	3.3	5.1
Paper	5.0	3.5	3.2	2.7
Chemicals	6.4	6.3	3.3	3.7
Petroleum refined	4.0	4.0	3.8	4.2
Rubber	7.4	5.4	3.1	2.2
Leather	0.9	6.1	2.8	1.2
Stone, clay, and glass	3.2	4.7	3.2	2.8
Primary metal products	1.1	0.9	1.8	1.8
Fabricated metal products	4.0	1.5	2.7	2.8
Nonelectric machinery	4.1	2.8	3.2	3.2
Electric machinery	7.6	4.1	3.8	3.0
Motor vehicles	5.3	3.9	3.6	2.9
Other transportation and ordnance	0.9	-0.6	3.3	4.4

Source: R. Epstein, et al. The Demand for Transportation. Wharton EFA, Inc., June 1978

4. Major elements of the national freight transportation system are suffering rapid deterioration of their physical facilities and financial health. This is particularly true for many railroads where tracks and equipment suffer greatly from lack of maintenance. Some private sector motor carriers, truck and bus, are hampered by an inability to properly maintain equipment. These carriers are returning such low earnings that their financial stability is threatened, as is their ability to meet the nation's varied need for high-quality, efficient service.

5. The scope and focus of current efforts to improve the technology of freight transportation are inadequate. There has not been sufficient progress toward using technology to improve the productivity of the system so that it can meet present and future freight demands.

6. The freight transportation system is not pioneering the technological change required to move toward realization of a national policy of shifting from oil as a primary fuel source to other energy sources for surface transportation or other modes of transportation where it is feasible and practical.

7. Serious problems now exist in transporting hazardous materials, including dangers to life and property, as well as the environment. These are expected to increase with increased volumes of movement, unless the transport is made safer and/or the production-distribution pattern is changed to reduce the distance of transport.

8. Appropriate data (preferably disaggregated) are not available to decision makers to the extent and timeliness required. The methods of acquiring, processing, and displaying information and of using it to predict the effects of proposed changes are often too expensive and unwieldy, and the data are often improperly aggregated.

It should be noted that all these problems affect the total freight system to some degree or other and not just one mode. In addition, most of the problems require for their solution institutional change, for the most part by government, as well as technological change.

The remainder of the Phase II report is devoted to an elaboration and description of the three categories of recommendations previously mentioned. The committee believes that there are many opportunities to solve the problems described, and the recommendations in the present report attempt to point the way toward practical solutions.

ROLE OF GOVERNMENT

In this chapter, primary emphasis is given to the role of government as a provider of transportation facilities, as a source of financial support for some facilities and services, and as the regulator that determines the types of transport facilities and services that other levels of goverment and private organizations can provide. These activities give the DOT a vital interest in improving the system, but require that there be careful coordination with other agencies. The government, thus, is the best place for overall planning and direction to improve the system. The roles of government as a developer of transport technology, and in data gathering and analysis, are taken up in later chapters.

In providing recommendations for research and analysis activities that relate to the role of the federal government, it is useful to consider the basic forms by which the government may intervene or affect the development of the transportation system. This is done in the next section and is then followed by a description of four high-priority research and analysis tasks.

DISTINCTIONS BETWEEN PAST AND PRESENT ROLES OF GOVERNMENT

The federal government can influence the development of the transportation system in two ways. First, it may provide facilities and services directly (Hoover Commission, 1949). Second, it may establish the ground rules or framework within which other entities can provide transport. In both cases, financial support through taxation is involved. Examples of the former include the provision of inland waterways by the Army Corps of Engineers and the air traffic control system by the Federal Aviation Administration (FAA) of the Department of Transportation (DOT). In other nations, railroads and airlines, and in some cases other forms of transport, are also provided directly by the government through nationalized corporations. However, in the U.S., most emphasis has been on the second; government as the provider of the framework within which others act. Thus, states and local governments provide a substantial portion of transport facilities, and private firms provide most of the for-hire services (including the nearly 50 billion dollars per year spent by the private firms for vehicles and their operation on the highways). The framework provided by the federal government, in certain instances, is constantly changing to meet changing needs.

Elements of this framework include such diverse activities as economic regulation of for-hire carriers, making overall rules affecting activities by other levels of goverment and private industries, determining or influencing the types and magnitude of federal funding of transport facilities, and setting the standards that must be met by state and local agencies to qualify for federal funding.

A primary, early goal of federal involvement in transportation has been to increase the ease with which people and goods can be transported throughout the U.S. (We later note some examples of resistance to new passenger and freight modes in anticipation of economic, social, or environmental effects.) One approach has been to promote the expansion of facilities; e.g., inducing the private development of western railroads through land grants. Another means has been federal aid to the interstate highway system. Other approaches include regulation, ranging from design standards to ensure that facilities meet minimal quality and safety levels (as in the case of highways), and regulation of prices and service to ensure that shippers and communities receive for-hire carrier services of high quality at a reasonable price. The particular mechanisms vary from mode to mode, and situation to situation, primarily because the major periods of development of each mode were separated in time. In all cases, the government's concern was to obtain the economic benefits of transportation, such as increased production and size of markets and the social benefits resulting from greater mobility and interaction, generally seen as "binding the nation together."

In recent years, however, the federal role has shifted to provide resistance to new developments because of adverse environmental effects and because of the recogition of the different effects improvements in freight transportation might have on different groups. The most obvious of the effects that concern the public are air pollution, noise, and the unsightliness of some major additions to the surface transportation system. More subtle effects include the relocation of people and businesses, such as might be expected within urban areas as a result of building better transport connecting the central cities and suburbs, which can lead to the migration of more affluent families from the central city.

The federal government's recognition of the positive and negative effects of changes in the transportation system has led to changes in the form of its involvement in transportation. One change has been the promulgation of regulations to reduce negative effects. Changes in design or operation can often bring these negative effects under control, particularly effects on the natural environment. Air pollution is being reduced as a result of the requirement that new automobiles meet emissions standards. (Emission controls for other sources have been established.) Another change has been the attempt by the federal government to give increased latitude to local areas to determine their own priorities for transportation development. For example, metropolitan areas have been allowed to invest funds previously earmarked solely for freeway construction in various forms of road facilities and public transportation. This has been accomplished by permitting local city governments and metropolitan

areas to match federal funds for freeways even if the states are unable or unwilling to do so, and to use the funds for other purposes. States have been allowed to decide whether railroad branch lines earmarked for abandonment will be continued through subsidies, partially using federal funds. As discussed in the committee's Phase I report and in an earlier DOT analysis, local areas (at least in principle) can evaluate the trade-off between positive and negative effects and make the final decision. It should be noted, however, that federal involvement frequently preempts such local decision making (NAAS, 1979a; DOT, 1977a).

With respect to intercity freight movement, the federal interest is broadening to include, at least to some degree, efforts to:

- provide a framework to permit various public and private parts of the transportation system to provide a level of mobility for freight movement adequate to support the economy and society;
- ensure that the various parts of the freight transportation system are efficient with respect to achieving the goals or tasks for which they are best suited;
- control environmental impacts of all kinds to acceptable levels, but through a benefit/cost assessment process;
- ensure safety of operations for both employees and the general public;
- reduce the use of energy, particularly that derived from oil, but also that derived from all fossil fuels and from other types of non-renewable energy sources;
- encourage the development of new technology to ensure efficiency in the domestic system (such as slurry and capsule pipelines and expanded use of computer technology), and to maintain foreign markets for transportation equipment (in such areas as aircraft, aircraft navigation, airport support, trucks and buses) as they affect balance of payments;
- maintain flexibility to meet changing requirements for goods movement and to ensure adequate capacity to meet special requirements, such as national defense needs in time of war; and
- encourage competition within and between modes when more than one mode can properly service markets, through regulatory reform to allow easier entry into routes and greater pricing competition. Relative subsidies among the modes should be reconsidered; for example, railroads build and maintain their rights of way, while motor carriers pay only part of highway costs, and waterways are government-subsidized.

These federal interests are discussed in the committee's previous reports (NAS, 1978; NAS, 1979a).

RECOMMENDATIONS FOR RESEARCH TASKS AND SPECIFIC DEVELOPMENTAL ACTIVITIES

Given the role of government as an agency of change in the country's transportation system, the committee believes that there are a number of additional actions that could be undertaken by the government or with its support, which would assist in achieving a more coherent and effective freight system. Some of the activities will be research efforts, but others are more in the nature of analysis and program development tasks.

(a) The research efforts that the committee believes to be of first order of importance are as follows:

Studies of the Processes Affecting Freight System Productivity. There is a need for research, in cooperation with industry and labor, that would better define the role the government can or should play in the organization of a more productive national freight network. As pointed out in the committee's Phase I report, and in an earlier Energy Research and Development Administration analysis, this need is especially important. Studies on increasing productivity would include attempts to improve the use of capital, fostering improved cooperation between labor and management, improving organization of the industry through merger and consolidation, and improving operations through standardization of technology and institutional arrangements. Research on productivity has direct relevance to the federal responsibilities in determining how to select appropriate modes for appropriate jobs and how to achieve more effective use of energy resources, in improvement of transportation technology, in the relationship to balance of payment issues, and in improving the return on investment in the national freight system (NAS, 1979a; ERDA, 1977).

- The committee recommends that studies be undertaken to develop recommendations that could stimulate institutional change in the regulatory area leading to improvements in capital productivity.

To conduct these studies effectively, an interdisciplinary team will be needed. The studies should involve capability for engineering analysis, consideration of various carrier management concepts, an understanding of the regulatory process and of the financial considerations, and a familiarity with the dynamics of change in transportation.

A number of recent analyses have indicated increased concern with the financial vitality of carriers and their relative capital access (Loving, 1978; NAS, 1979a). Better capital utilization in the several modes of intercity freight carriage may promote efficiencies that could foster better service and higher earnings. Previous studies on railroad productivity have noted that such developments might be quite important in view of the difficulties encountered by many carriers in the capital markets (U.S. Congress, 1961; Task Force on Railroad Productivity, 1973). With respect to the railroad industry, studies

more comprehensive than those previously performed should be undertaken on the following topics: potential of a national freight car fleet, processes for reducing circuitous routing, and the feasibility of large-scale implementation of the concept of assigned fleets and agreed charges. For the motor carrier mode, a study should be undertaken to determine the effects, both on vehicle efficiency (ton miles per gallon, for example), and on highway maintenance, of differing regulatory certification requirements among the states.

The potential for automation in the several modes should be examined further, and alternative methods of introducing automated processes should be explored. There is an extensive amount of deferred maintenance, particularly on the infrastructure (rails, roads, airports, etc.) and clearly a need for study to develop more efficient maintenance practices (that is, more rapid, cheaper, and more durable repairs).

- The committee recommends that cooperative studies be undertaken of the possibilities for improvement in labor productivity. DOT should encourage, support, and help finance such labor-related research, in cooperation with other agencies, such as the Department of Labor, and all parts of the affected transportation community.

As discussed in the task force report on railroad productivity and in the railroad research study, some work rules and craft distinctions limit productivity of transportation workers (Task Force on Railroad Productivity, 1973; NAS, 1977a). These apply primarily to railroads. Comprehensive federal job protection programs covering rail and transit workers have offset potential productivity gains from technological innovation. Further, the long-term adversary posture that exists between management and labor in some portions of the transportation system often leads to poor communication and little joint commitment to promote efficiency (NAS, 1977a). Studies should be initiated aimed at greater labor productivity through the introduction of new freight handling technology in yards, depots, and forwarders' facilities, and also through attention to savings by more extensive use of intermodal transport.

As described in the Phase I report, there have been successful cooperative efforts that resulted in more freight being moved in less time, with fewer people, and with no overall loss of jobs (St. Louis Project, and the Providence and Worchester RR Profit Sharing Plan, NAS, 1979a, pp. 40 and 43).

Studies of the railroad system should be undertaken to evaluate the costs and benefits of specific work rules, joint basis for pay, significance of craft distinctions, use of arbitrary pay scales, costs of yard-versus-line jurisdiction, and the possibility of moving the entire industry to a salaried basis. Similar studies might be undertaken for truck, waterway, and air freight services. The experience of other industries in eliminating inefficient work practices should be assessed for ideas that might be adopted to improve performance.

The problems of labor productivity differ throughout the several forms of industrial organizations associated with the modes--each mode

generates its productive specializations, occupational mix, and accompanying culture. To properly take account of these differences, labor productivity studies should be designed as part of social organization studies that include comparisons across the various modes.

Given the scope of such studies, they may well require substantial levels of funding. The talents that would be required to pursue these matters would include labor specialists, individuals who understand carrier operations, experts in public policy as it pertains to transportation labor, and specialists in finance and management.

• The committee recommends that there be established a comparative study of labor in the several modes, as companion research to the above, to lead to better understanding of labor-management relations, labor recruitment, compensation, training, and conditions of work as they affect the individual freight services and the overall transportation system. The committee suggests that the department consider the possibility that other organizations outside DOT might advise them on how the research in these areas should be designed and conducted. The efforts of the Task Force on Railroad Productivity made a start toward such a comprehensive study (although with a focus on rail), and as previously noted, made some limited but important improvements. It has now been some six years since those studies. New efforts would be timely.

The objective of research in this area would be to treat, on a comparative basis, cross-modally, the characteristics of labor and labor relations which derive from the different technologies and occupational specializations required by each mode. Consideration should be given to union interests and concerns at all levels. For example, financial pressure on local leaders may cause them to support issues that national leaders feel should not be imposed on all locals. Such a study would develop a better understanding of the characters of the various labor organizations and of their leadership. An evaluation of the need for training of personnel should be included in these studies.

All three areas of study, capital productivity, labor productivity, and a comparison of labor in the several modes, are interrelated. The latter two in particular involve behavioral considerations. All need careful planning. To define such problems and research areas, and to approach intelligent solutions, ideally requires a social theory of transportation. Such a theory would offer a framework to conceptualize the role of transportation systems in the society as a whole. The theory should specify the relation of transportation systems, not only to economic systems, but also to such aspects of society as the distribution of political power, the maintenance of social order, the functional specialization of regions, population distribution, and kinship networks (NAS, 1979a). It would require a clear statement that relates transportation to economic, political, educational, religious, physiological, legal, and other forms of social organization. While no truly integrated theory has been advanced, the foundations of such a theory have been laid down by a number of authors (Cooley, 1894; Bright, 1924; Wiedenfeld, 1935).

An addition to such theories was begun in a paper sponsored by the DOT as part of the committee's study of short-haul transportation, and continued during the freight system study (Klausner, S.Z. et al., 1977). The research efforts proposed, if properly designed, will contribute to the development of such a theory. The very effort to deal with problems internal to the transportation system will require the clarification of the system's external relations. However, it will be necessary to initiate research to develop long-range and fundamental thinking to overcome the intellectual fragmentation that, until now, has hindered problem clarification and the proposal of workable solutions.

- The committee recommends that a review of merger and consolidation policy be undertaken to determine the possibilities of improvement to productivity.

This review of merger and consolidation policy should not require a major financial commitment from DOT. A considerable body of literature already exists in this field. Much of the work would involve the integration of existing materials.

Studies in this area will help to assure that federal policies promote the benefits of carrier mergers and consolidations while providing safeguards against undesirable reductions in competition. Combinations of carriers, both intramodal and intermodal, may result in a variety of cost, service, and market improvements. However, public policy must weigh these potential benefits against the potential negative side effects (such as possible reduction of service to communities with low density traffic, and possible loss of jobs).

Federal policies governing intramodal and intermodal combinations have varied over time, as has the intensity of the merger and consolidation movement (NAS, 1977a). Interest has been growing recently in railroad and airline consolidations. Consolidation of several modes has been receiving more attention as the first step in creating transportation companies (DOT, 1978c).

A major study of merger policy, including protection of employee benefits, is urgently needed. The results of earlier combinations appear to be mixed, and considerable analysis should precede any efforts to use mergers to restructure the industry. The potential impact of job guarantees on the postponement of consolidation-related savings should be invested. The desirability of promoting further concentration in the several modes of intercity carriage should also be undertaken. In the intermodal context, attention should be given to identifying those modal combinations that seem to offer the greatest benefits. The Canadian experience, where one multi-modal company is private and another is publicly owned and operated, has shown cases where economies and efficiencies can be achieved with the freedom to manage all modes. In the U.S., such arrangements are not now possible.

- The committee recommends research on the possibilities for improvement of transportation productivity through selective standardization. The research should include cooperation from industry and users, but DOT could take the lead. The research might focus on rail freight, but should include trucking, maritime, and air

freight operations, and intermodal transfer, possibilities for standardization.

While standardization in this context refers primarily to technology and manufactured parts, it can be extended to include standardization of load, length, etc. for motor carriers to optimum configurations balancing vehicle efficiency and highway maintenance costs.

Research on standardization should include investigation of opportunities for pooling equipment within the modes and possibilities for universally acceptable, multimode equipment that might improve the use factor (without violation of existing antitrust laws). Examples include greater use of containerization to increase intermodal compatibility, and expanded standardization of handling equipment and its use. Through careful analyses of current and proposed types of improved service, including consideration of intermodal possiblities, an assessment of at least the approximate magnitude of savings could be made.

(b) The analyses recommended below are expected to have some payoff in the short term, in contrast to the longer term research characters of the list under (a) above.

Analyses of Needed Revisions in Economic and Safety Regulation. Based on earlier reports and its own studies, the committee has concluded that extensive revisions to the freight system regulatory process, particularly to railroad regulatory processes and procedures, are required to serve the federal interest (NAS, 1977a, pp.20-24; DOT, 1977a, pp. 49 and 54; NAS, 1978, pp. 15-23; NAS, 1979a, p. 7 and pp. 28-33).

- The committee recommends that a study of the economic regulatory structure be undertaken to improve the overall process. The objectives of regulatory reform would be to restructure and update the regulatory process, recognizing the needs and interests of the nation in improving productivity, which are shared with the shippers and the carriers (both management and labor).

The initiative for the action rests with the Secretary of Transportation, with support from the executive and other branches of government and from the various freight service suppliers, all representing the public interest.

Such government actions would eliminate ineffective rules and procedures and reestablish the original premises of the regulatory process through assurances of appropriate treatment for the various modes (for example, liberalizing entry into service of routes by adjusting either subsidies or rate levels), simplification of the implementation and appeal processes (particularly as they relate to rate levels), and the provision of incentives that (even with regulation) assure both competition and efficiency. The committee recognizes the steps already taken by the Secretary of Transportation and Congress to deregulate the airline industry and to move toward change in the regulatory structure for other modes; however, the committee believes an effort toward reform of the economic regulatory structure over the long term would still be valuable.

Fundamental to a study of regulation is a broader study of the social process of rule making and an evaluation of the organizational impacts of rules--whether promulgated by the operators, local or state governments, or regulatory agencies. In a larger sense this would be a study of the transportation policy-making process with provision for assessing the social impacts of transportation policy.

- The committee recommends that a detailed review of safety regulation be undertaken.

The objective of such research is to apply rigorous cost-effectiveness procedures to all existing freight system safety regulations and to develop a process to be applied to all future regulations. The recent report on railroad safety performed by the Office of Technology Assessment is an excellent first step (OTA, 1978). Technology for safety improvement is discussed in the following chapter.

(c) An Evaluation of a Reconstituted, Efficient National Rail Network:

The committee recommends that a careful study be undertaken of the country's needs for a national rail network. Alternatives should be explored as to demand, costs of various levels of service, and overall feasibility.

It is the committee's opinion that a key to improvement lies in extensive regulation reform for the railroad industry, that such change is in the public interest, and is now politically feasible. Although the committee does not suggest extremes of deregulation or "no change" in regulation, it notes a rapidly emerging public sentiment for reevaluation of regulation and changes where needed. The analyses and implementation actions required here will, in many cases, require a look further into the future than has been done in previous analyses. In short, the committee perceives that regulatory reform is needed to allow abandonment of unneeded rights-of-way, to foster consolidation and sharing of elements of the system, and to provide incentives for a more economically efficient and self-sustaining status for the railroad industry. This is primary to the federal goal of an energy-efficient transportation system that requires a minimum of subsidy.

The objective of regulatory reform is to overcome the present fragmentation of the rail system, to modernize it on a nationwide scale, to achieve a high utilization of equipment and service and, ultimately, to attract the necessary capital to keep the system self-sustaining. This need was recognized by Congress when it enacted the Railroad Revitalization and Regulatory Reform Act of 1976 (4-R Act). That legislation contained provisions directing the Interstate Commerce Commission (ICC) to streamline and modernize the rail rate regulatory structure and establish procedures to assure adequate reserve levels for the carriers. DOT was charged with the responsibility of administering a program of financial assistance, evaluating the capital needs of the industry, and assessing ways to revitalize and restructure the rail system so that its inherent advantages can best be utilized. Work in this area to date is

presented in DOT's recently released report entitled A Prospectus for Change in the Freight Railroad Industry. Restructuring work is now underway at DOT under the authority of the 4-R Act. Efforts are concentrated on coordinating attempts by the carriers themselves to change the existing system through the trading of market opportunities, right-of-way consolidations, and other changes short of total merger.

Accomplishment of this goal and related objectives will require that DOT (Office of the Secretary and the FAA) extend its work on the definition of the necessary national network of rail transport. Alternative plans should be proposed, costs estimated, feasibilities of the varied arrangements assessed, regulatory revisions identified, and an implementation schedule developed in cooperation with the ICC.

The need for such an effort is imperative. The likelihood of success depends on strong national leadership and cooperation from the legislative and executive branches (including the regulatory agencies). DOT may seek to develop and use objective criteria in defining a "necessary" rail network or, more broadly, in outlining standards for federal investment in transportation, but it does not have the authority for inland or deep-draft navigation policy. Therefore, there is a need for a comprehensive look at national transportation policy (DOT, 1977a: DOD, 1976).

(d) A National Freight System Planning and Programming Activity:

The committee recommends that consideration be given to the organization of a national freight system planning and programming activity within DOT with the active participation of shippers and other users.

The objective would be to provide a continuing plan of coordinated action for the several, now relatively uncoordinated, portions of the national freight system (rail, highway, air, water, and pipeline). The success of this effort would also require extensive coordination at the federal level, but DOT can and should take several immediate steps. First, as specified in (c), above, DOT should develop and use objective standards for federal investment in transportation. Second (if not accomplished as part of (c)), criteria should be developed for determining the necessary segments of a national freight network. Third, this national freight system activity should coordinate all DOT programs and spending carried out by the modal administrations. It should also develop liaison with other government freight transportation activity, outside DOT's program jurisdiction, such as Department of Defense (DOD) programs, as well as inland and deep-draft navigation activity where standardization of containers and handling equipment for all modes, including maritime, is of great importance (DOD, 1976; Jane's, 1974-1975). During its study, the committee explored Defense Department normal and emergency freight needs, including hazardous cargo, with the DOD's Military Traffic Management command. The present active cooperation between DOT and DOD should be extended into this planning activity. Finally, the activity should ensure that needed research and policy activity is carried out in subject areas (such as trucking operations) that do not fall within

the implicit jurisdiction of any operating agency (NAS, 1978). This planning activity should be closely connected and provide close coordination with all DOT organizations involved in the development of national transportation policy.

ROLES OF TECHNOLOGY

DISCUSSION

Introduction

The committee recognizes that the primary difficulties of the nation's freight system stem from institutional practices and inhibitions as well as from technological deficiencies (NAS, 1979a). While the importance accorded the institutional factors is appropriate, the committee does not underestimate the role technology has played, and should continue to play, in the evolution of the nation's freight system. The committee believes that all the elements involved in making up the climate for innovation, and even for more evolutionary changes, are interconnected and should properly be treated together.

There are now increasing freight demands coupled with rising expectations for economic efficiency, energy conservation, and preservation of environmental quality. As previously noted, with the average annual estimated growth rate of the GNP at about 3 percent, and that of freight movement at 3.1 percent, both the GNP and freight movement (in ton-miles) are expected to more than double by the year 2000. Air carriers are forecasting a much larger percentage growth than other modes, although total air ton-miles remain a small fraction of overall freight ton-miles (ATA, 1977-1978). Waterway traffic depends considerably on future policy decisions, but is now expected to grow at about the rate of the GNP (DOT, 1977a; AWO, 1975). These growth trends, and the many changes in the composition of freight to be moved and the ways it will move, indicate need for freight system change.

The present and forecasted growth indicate the need for a substantial upgrading of freight transportation capability generally, as well as emphasis on longer-range improvements (NAS, 1979b; DOT, 1977a). A great deal of freight system research and technology development has been undertaken; e.g., in the rail systems area (DOT, 1977c). However, in view of the forecasted doubling of freight demand by the year 2000, additional work will be needed--not only on rail, but also on other modes and the overall system itself.

The committee concludes that technology, in the form of hardware developments and operations improvements, is a key element in assuring an increased contribution from the freight system to an improved and vital national economy (NAS, 1979a).

Specific Examples of Technical Programs Needing Expansion

Freight System Productivity

A number of recent studies have identified the pressing need for increased freight systems productivity and economic efficiency, particularly in rail systems. Productivity was identified as "what may be the greatest single problem in the rail industry" (NAS, 1977a: Ward, 1977; Maio, 1976).

Several studies have been conducted to assess the costs of different approaches to improved systems productivity. These have concluded that intermodal services (i.e., coordinated combinations of air, motor truck, pipeline, rail, and waterway services) can provide improved service at lower (relative) overall costs (Reebie Associates, 2976-2977; DOT, 2977a; Campbell and Katell, 1975). An example of potential savings was found in the type of operation practiced in Canada. Both Canadian National and Canadian Pacific (one nationalized; one private) are transportation companies and have all modes under their management. They are able to ship cross-country, using combinations of truck, rail, water, etc., as is most efficient for the job. In the U.S., regulatory structure makes such arrangements much more difficult, if not impossible, in some instances. The waterways and slurry pipeline industries maintain that there are additional locations where the use of those modes could bring greater efficiency (AWO, 1975; Jennings, 12976). The committee concurs in these conclusions and recommends that actions be taken to encourage demonstration of intermodal advantages, including port operations, on a sufficient scale to justify broader application (Janes, 1974-75).

As an adjunct to such efforts, the committee suggests that studies to devise better uses of equipment would be valuable to stimulate improvement to freight system productivity. Examples of methods to improve the use of equipment are:

- Carriers presently have considerable advance information on the varying demand for their services. However, they do not appear to make sufficient use of this information in advance and routine scheduling of services, in consolidation of shipments, or in providing varying levels of service at varying costs. Use of computer-based procedures, perhaps on a national basis, with sharing of costs and access by all types of carriers, may offer advantages for some applications.

- Equipment standardization should improve interchangeability and utilization. For example, national standardization of motor vehicle sizes and weights could help expedite both transcontinental and local delivery of motor freight. Such standards would be helpful in planning for possible upgrading of highways sytems, particularly of the interstate system, in

resurfacing, reconstruction, or maintenance programs (DOT, 1976a).

- Additionally, studies should be carried out on more efficient use of equipment to reduce empty mileage of both rail cars and motor trucks. For example, methods of cleaning tank trailers and tank cars more quickly and easily, if developed, would provide much better use of such equipment.

Freight System Safety

There is a continuing need for attention to freight system safety (DOT, 1977a, p. 208; DOT, 1978b, pp. 35-36). One prime area for improvement concerns the shipment of hazardous materials, where additional efforts should be expended in the design and provision of specialized containers (DOT, 1977a, p.73-75, p. 208; DOT, 1978a; DOT, 1978b, p. 35; OTA, 1978, p. 14 and p. 35; Carnegie-Mellon, 1978).

Further study is needed to improve the interior design of cabs and occupant positions for locomotives and motor trucks. Close coordination is required between establishment of new safety standards and regulations pertaining to these stamdards and the provision of support for research and development efforts in technological areas required to justify needed changes (OTA, 1978, p. 13).

An additional area requiring continued study is the improvement of systems and devices for railroad grade crossings. Grade crossing accidents continue to be the major cause of fatalities in railroad operations, accounting for approximately 65 percent of the fatalities resulting from all types of railroad accidents during the period 1965-74 (NAS, 1977a; OTA, 1978, pp. 14-15 and p. 135).

Major contributors to rail accidents and highway accidents have been deteriorating tracks and deteriorating roads. Improved maintenance capability and funding to upgrade the system are required.

Freight System Energy Conservation

Efforts to improve productivity and increase operational efficiency will also provide improvements in levels of energy conservation. Studies extending current works are needed to enhance these improvements; e.g., further reduction of aerodynamic losses in motor vehicle tractor and trailer design (Steers et al., 1976). Another set of energy conservation initiatives involves improvement in matching of individual freight services and their inherent operational energy efficiency to the shipment of particular commodities. For example, particularly for fairly long distances, bulk commodities like coal and iron ore are shipped more efficiently, measured in terms of ton-miles per unit of energy, by waterway and rail (particularly in unit trains) than by motor truck (ERDA, 1977; Delta, 1976; Library of Congress, 1977).

Technology has played a key role in providing the freight system and services. History shows a continuing improvement in equipment and operations--both evolutionary, as in propulsion systems development, and revolutionary, as in the application of long-distance pipelines (NAS, 1979a). The committee believes that technology should continue to play a key role in improving freight system productivity, safety, and energy conservation. It is also believed that technology can satisfy these and other system objectives within broader national objectives (PMM, 1976; DOT, 1976b). With respect to environmental protection, favorable balance of payments, full employment, and job security, technology has a substantial role, opportunity, and challenge.

However, in a number of areas, there is an insufficient amount of such freight system research and development being conducted in the U.S. There is a lack of activity related to private (carriers and equipment suppliers) and to public (primarily federal government) interests. We believe the lack of activity exists despite the need and opportunity, not only because of an unfavorable regulatory environment but also because of the associated weak economic situation and the resulting investment risk and shortage of capital funds. If this situation is to change, action on several fronts is necessary at the federal level.

As discussed elsewhere in this report, government initiatives are required in policy, planning, coordination, and regulatory reform areas. However, the committee recommends coordinated action also in the technology area--in initiatives and in financial support of research, development, demonstrations, and applications.

Policy and legislative initiatives taken by the federal government in freight system areas should provide encouragement and incentives for technological innovation and for the development and application of new technology. The incentives might include a variety of things. Positive encouragement could be provided by granting greater tax credits for research and development investments. Another form of encouragement could be matching funds for private venture research or applications in designated priority areas.

In addition, other incentives could tie authorizations for such things as rate increases to demonstrated improvements in service level, to decreases in losses from damage or theft, or to the provision of reliable service over an extended pre-specified period of time.

DOT should embark upon a selectively expanded freight systems research and development program. There should be provisions for innovation through the better use of existing technology. There should be a matching program, at approximately the same level of effort, for the development, demonstration, and application of new technology.

These two elements of the expanded program should be subdivided further into projects on components and projects on overall systems. Examples of needed component research, development, and application include work in such areas as:

- propulsion (e.g., improved specific fuel consumption and reduction in emissions for aircraft and motor vehicles, electrification for intercity and local rail);
- guidance and control (improved enroute and local air traffic control, use of modern technology in railroad signalling and route control and in improving rail vehicle stability, and improved city traffic control);
- aerodynamics (airfoils, winglets, stability);
- friction and wear (bearings, wheels, rails); and
- operations research (air and ground traffic, freight yards).

Examples of needed systems research, development, and application include:

- intermodal operations (aimed at treating goods movement as a system--truck to piggyback rail to truck, or truck to barge to truck, etc.);
- network utilization (study to determine where rail abandonments are feasible, connector arrangements between modes, improved maintenance for rail and roads, etc.);
- matching services to markets (studies to identify needed institutional change to permit better system use); and
- energy conservation in all modes (careful selection of the most fuel efficient combination, or the most efficient use of a mode, as in the special case of unit trains to avoid switching and circuitous routing costs).

One way or another, the nation will almost inevitably be making large investments in freight transportation. If it is to make them wisely, it will be necessary to understand the implications of alternative paths of transportation system evolution, given the likelihood of changing market needs and opportunities as well as changing technological capabilities.

Only the federal government has the scope of interest to apply such a crossmodal and multimodal perspective to the changing economic needs and to economic enhancement of the nation. The committee, therefore, recommends that a broad crossmodal and multimodal program of systems research be strongly supported.

IMPLEMENTATION OF RESEARCH RESULTS

Although research and development offer opportunities for improved productivity, they will not be effective unless the user community is motivated to use the research results. Consequently, it is essential that research and development be undertaken in a fashion that enhances implementation.

There are mechanisms of information storage, retrieval, and dissemination to aid in applying new technologies to transportation in both public and private-sector institutions. But there are obstacles

to information flows, e.g., a lack of knowledge on how to use such systems, and other factors that slow technology transfer. Every effort should be made to involve customer and user in the process in order to minimize the time that is invariably lost in the transfer of technology. Consequently, studies on enhancing the deployability of technology are warranted.

Each research project should involve potential users, clients, and beneficiaries in its conception and direction in order that they be apprised of the work and guide it in ways that yield results useful to them. There is also a need for consideration of the roles of the many government agencies that have overlapping responsibilities, (e.g., DOT, Environmental Protection Agency, Department of Energy, state agencies, etc.) for matters that should be treated in these research areas.

Technology has the potential to improve substantially the nation's transportation system and thereby enhance the national economy, standard of living, and quality of life. Although many technological advances can be implemented without major changes in the organizational or institutional arrangement of the present transportation system, adoption of many other advances will require coordinated changes in such arrangements, presumably with a sharing of benefits among all parties involved.

CONCLUSIONS AND RECOMMENDATIONS

The committee concludes that there are substantial opportunities for the application of existing and new technology in the provision of an improved U.S. freight transportation system, while at the same time contributing to the realization of such national objectives as environmental protection, a favorable balance of payments, full employment, job security, health and safety, and energy independence. These opportunities include the following:

- Improved systems productivity and greater economic efficiency are possible. They can be provided through such actions as intermodal services, advance routing and scheduling of shipments using a national shared computer network, and equipment standardization (e.g., national motor vehicle size and weight standards).
- Substantially-improved freight system safety is possible. It can be provided in areas ranging from the shipment of hazardous materials (by such means as the design and provision of appropriate containers), to equipment operator protection (such as cab design in locomotives and motor trucks), and improved railroad grade-crossing warning devices.
- Energy conservation is possible. Examples promising savings include improvements in propulsion system efficiency, continued attention to potential aerodynamic losses in motor vehicle tractor and trailer design, and greater use of shipping innovations. Offering good potential are

innovations such as unit trains for coal shipments and intermodal systems and freight consolidation services to ensure the most efficient use of the system where possible. It is important where feasible to work toward the policy of shifting from oil to other sources, such as electrical power produced from coal, hydro-electric generation, nuclear generation (for example, for use on electrified railroads, local public transport, local freight movement, etc.), and to assess environmental impacts as well as the technical aspects.

However, the committee believes that despite the potential suggested in these examples, there is an insufficient amount of freight systems research and development being conducted in the U.S. This lack of effort is apparent for both private (carriers and equipment suppliers) and public (primarily federal government) interests.

Therefore, the committee recommends that the federal govenrment embark upon two coordinated actions:

(a) Introduce policy and legislative initiatives (particularly those in regulatory areas) that would provide incentives for freight system carriers, shippers, and suppliers in the deveopment and application of new technology and technological innovation aimed at improving productivity and safety. The incentives could include such things as tying approvals for rate increases to demonstrated improvements in productivity, as well as favorable tax credits for research and development investments.

(b) Mount an expanded freight system research and development program directed by DOT, but in cooperation, as appropriate, with others in the transportation sector. As an important element of an approach to solutions for the problems previously identified in this report, the committee makes the following specific recommendations.

- The expanded program should include support for the development of new technology as well as better applications of existing technology.
- The program should have provisions for work on overall systems, such as intermodal development, as well as on such components as guidance devices and propulsion.
- A special section should be provided in the program for the encouragement of technological innovation. Examples include radio-dispatched flexible routing and scheduling in freight pickup and delivery services.
- While much of the technology program may be initiated or managed by DOT, a variety of organizations and interested parties, including labor, should be involved in various aspects of the R&D efforts. Examples of organizations appropriate for conduct of freight systems research and development include carriers, equipment

suppliers, universities, consulting firms, private and nonprofit research organizations, shippers, or combinations of these organizations.

INFORMATION, ANALYSIS, AND ASSESSMENT CAPABILITIES

THE FUNCTIONAL ROLES OF INFORMATION HANDLING AND ANALYSIS

Freight system information, analysis, and assessment capabilities are of critical importance to a variety of decision makers--government agencies, the Congress, and industry--to help them identify problems, pose and evaluate solutions, and rank actions according to priority. "Information" as used here is meant to include not only data on freight systems demand, use, and levels of service, but also the process that transforms data into output forms that can help decision makers. Current capabilities in these areas are inadequate. Present methods are unwieldy, expensive, or both. For that reason, some questions cannot be answered because of the resulting lack of either the required data or the analytical capability to interpret what data are available.

There are several ways in which information and its analysis serves the decision-making process.

- The first is concerned with the problem of understanding the current system and its operation for use in decision making, which might enable identification of the problem spots that currently exist or potential opportunities for improvement. These problems range from inefficiences within a particular mode to the uneconomical usage of the total mix of services. With better knowledge of the system and its operation, opportunities for improvements (including proposed responses to environmental, financial, energy, and safety consequences of current operations) might be identified more easily.
- A second use for an improved information and analysis capability is to provide a context for the formulation of alternatives for improvements to the freight system. Possible improvements may result from institutional change, capital investment, technological advance, or changes in operational strategy.
- A third function requiring improved information and analysis capability is the evaluation of proposed alternatives. The evaluation should include not only the cost and performance characteristics and, therefore, the economic worth of a change, but also the broader consequences of change. These consequences relate to energy, safety, and the environment, to the longer-term impacts on the structure and productivity

of the economy, and to the consequent changes in the spatial distribution of econonic activities and population.

- The fourth function in which an improved information and analaysis capability can assist decision makers is in anticipating or better forecasting future flows on the network of a proposed transport system due to changes outside the system. External changes include changing volumes of freight flow resulting from the state of the economy, the changing mix and pattern of freight flow due to changes in the production process and its impact on spatial distribution, and changing environmental protection or safety requirements.

The description, formulation, evaluation, and forecasting functions require not only the data and analysis capabilities needed to model transportation demand and supply, but evaluation criteria that are consistent across the modes and measures of output that are broader than just economic viability and service quality. These functions also embody a notion of forecasting which encompasses more than just projection of magnitudes of flow, but is predictive of the changing mix and patterns of flow as well.

The information, analysis, and assessment capabilities that are needed should consist of procedures that transform the available data relating to a particular situation into meaningful information for decision making.

CAPABILITIES REQURIED

Research on a complex operation such as the freight transportation system proceeds by iteratively collecting data, analyzing it, formulating theory, and collecting more detailed data on the phenomenon, followed by more focused analysis, further refining of the theory, and testing of its validity. There is always uncertainty at the edges, new inconsistencies to explain, new theory, and improved models that shed light on the way in which the new data observations should be collected and processed, and there are always human inertia and practicalities to overcome. The collection and processing of data are, therefore, fundamental to the development of knowledge. However, the description of the process is not meant to imply the need to mount a massive effort. A selective approach is intended.

Disaggregated data, such as samples of the tons of freight carried by individual modes, are collected by many agencies. Such individual observations may be combined or aggregated in many ways, for many purposes. Though the use of data involves the aggregation of individual observations, this aggregation necessarily throws away information during the aggregation process. If a new policy question is to be answered, the aggregated data may not be able to shed any light on the answer. One important aspect of data storage and retrieval is, therefore, the opportunity for the use of new computer

techniques for strong disaggregate data and factoring up the results to answer new questions from the same set of original observations.

There are a number of problems that must be overcome to allow efficient use of such data and analysis in the decisions faced daily by policymakers. The first of these is the very large cost that would be incurred if one tried to develop a large enough data base to be able to answer any policy question directly by suitable aggregations of the data base. The complexity of the freight transportation system and its attributes insures that there is insufficient money to sample all the events needed to insure statistical significance in every case using sampling alone. However, there are new techniques and methods to address this problem directly. Reasonably small samples can be used to develop disaggregate behavioral models by means of which much of the "behavioral" content of the system can be defined. When used in coordination with existing information about the system, and new methods of iterative scaling, these models can then be used to produce aggregate results suitable for decision making. (A number of these problems and proposed solutions can be found in NAS 1979a, Appendix D.)

The complexity of the freight transportation system and its attributes calls for sophisticated, efficient sample designs to provide basic data usable for a variety of purposes, including studies of change over time. Care must be taken to ensure that data from these souces and means of achieving the previously mentioned variety of purposes are not lost in demands for massive descriptive or regulatory data. Examples of some of the many sources of existing data are: 1) the Census of Transportation-Commodity Transportation Survey, 2) the ICC One-Percent Waybill Survey, 3) the FAA Truck Use Survey, 4) the Continuing Traffic Study-Truck Use, 5) Corps of Engineers 100 Percent Sample, Inald Waterways, 6) Fruit and Vegetable Unloadings, Department of Agriculture, 7) Civil Aeronautics Board, Sample of Air Waybills, 8) U.S. Postal Service, 9) Export/Import Census of Inland Movements, and many special surveys such as trailer-on-flat car movements. With such a mass of data, it is evident that careful design of an overall system is needed.

Holding large-scale data bases in aggregate form is also wasteful in terms of initial data collection, storage, and retrieval. Instead, data should be held in the disaggregate form in which it was originally collected and aggregated up as needed for use in policy decisions. This is considerably more direct and could be more easily used by policymakers, over the short term (TRB, 1977).

Finally, confidentiality restrictions pose a barrier to the collection, storage, and use of data in the disaggregate form. Certainly, the collection, storage, and dissemination of data as currently practiced in the Census of Transportation does not allow access to the data in the disaggregate form. The philosophy of disclosure employed by the ICC with the Rail One-Percent Waybill Survey is much more consistent with the uses of data described here. Alternatively, greater selectivity should be used in data gathering, and only data that can be released in the disaggregate form should be collected. Finally, the data (even confidential data) can be used to calibrate behavioral models. This "condenses" the information content

of the data into the coefficients of the model, and while it does not reveal the individual freight transfers of the shippers, it still allows us to make "predictions" with the model which are useful in decision making.

Both continuing and single time period data collection are required because some of the impacts change over time. This means that in addition to the single time period data collection efforts described earlier, they should be repeated over several time periods if they are to be of maximum usefulness. Caution is urged in order to avoid past pitfalls, however, since institutionalizing the data collection process can produce a big, inflexible, and expensive data collection bureaucracy and massive, difficult-to-use data bases.

Current methods of gathering, storing, and using data in conjunction with present-day modeling practices are inefficient. New techniques are becoming available for changing current practice. Therefore, research in this area appears likely to have a high return (NAS, 1977b).

RECOMMENDATIONS

DOT should sponsor a sampling research program on data collection and evaluation methods for freight commodity flow as follows:

(a) Establish a library of basic disaggregated data sets describing the freight transportation system and its performance for use in the support of policy formulation and implementation. Develop procedures for the operation and effective use of this library. Full advantage should be taken of useful data sets that already exist.

(b) Design the data management facilities to be used not only by government and private-sector policy makers, but also by the DOT staff and planners in the modal administrations, the academic researchers, and the research firms that serve as contractors.

(c) The facility should be estabished in DOT. Actual data collection, analysis, and modeling activity could be performed within the various modal administration of DOT, as well as in other agencies.

(d) Initiate a series of pilot applications and case studies to assist in improving use of the data in the description, formulation, evaluation, and assessment processes described above and in posing the inquiries and special data collection efforts that need to be undertaken.

(e) Support the development of new methodologies on a consistent basis over time, even if at a modest level. The data collection and analysis program recommended here attempts to depart from previous programs in a number of significant ways designed to make it more relevant to policy analysis, easier to use, and less expensive. These objectives form the basis for the recommendations:

- Each data collection effort undertaken should be designed to increase the understanding of one or more causal mechanisms.

- Full advantage should be taken of knowledge of existing causal mechanisms to reduce the size of the data collection effort.

- Data should, where possible, be gathered according to a sample plan that will allow use of existing and available statistics.

- Extensive technical advice from experts in sampling, data collection, and data management from both inside and outside government is needed in order to devise a comprehensive set of data plans and a collection program focused on analysis and research purposes. This data program should emphasize flexibility and richness, rather than precision or massive detail.

The principal concern should always be a better understanding of causal relationships and their use in policymaking.

APPENDIX A ISSUES AND CONCLUSIONS--PHASE I REPORT

Issues

In its Phase I report the committee identified five key issues that encompassed the multiplicity of difficulties distributed throughout the freight system. These are:

- What approaches could best serve to stimulate and improve the process of Technological Evolution? There needs to be developed better cooperation between public and private sectors for incorporation of new transport technologies into the existing system.
- How may the Government Participation be improved, and what are the appropriate roles for government to undertake? A determination needs to be made of the most effective methods of implementation for improvements, and a proper balance achieved in the mix of federal, state, regional, and local governments involved in the process.
- What Evaluation Criteria are acceptable for determining the extent and form of government participation? In the mixed public and private economic structure in transportation improvement is needed in the determination of relative shares of support (public/private) for the system. Improved criteria are needed to aid in that process.
- What are the principal factors required for Creating Incentives to Improve Productivity? There needs to be established a suitable environment for increasing the productivity and efficiency of freight transportation service through coordinated efforts of labor, management, and government, including regulatory agencies.

- How may the process of Demand Forecasting and the Understanding of Spatial-Distribution Interactions be improved? Improved analysis and forecasting methods are needed to improve the understanding of the long-term implications for freight transportation, of economic, energy related, environmental, and safety problems and alternatives for solution.

As part of the analysis many problems were identified and conclusions developed in each of these issue areas concerning needed actions that might lead to solutions.

Conclusions

A very brief reference to some of the major conclusions of the Phase I report is provided here for readers without ready access to that publication. These are:

1. Technological Evolution: The principal opportunities for technological improvement are:
   - Strengthening the flow of technology to industry components;
   - Developing and using technologies that would improve the interconnections of transportation systems, thus permitting increased intermodal activities, and better use of each mode; and
   - Identifying and exploring new systems technologies.
2. Government Roles: The existing and emerging government roles that may require study and reassessment are:
   - Formulation of consistent public policies;
   - Regulation;
   - National transportation system analysis;

- Decisions concerning the degree of public and private ownership and operation;
- Stimulation to technological innovation and application of new technology.

3. Developing useful criteria for evaluation of a mixed public and private economy: Government decisions affecting freight transportation should be reached by comparing the benefits of each change under consideration to the added cost of that change. These added costs would be the amount required to fully compensate the carrier, public or private, for providing the otherwise uncompensated service.

4. Productivity: The committee concludes that:
   - Efficient management, good relationships and communications between employees and management, and cooperation among government, labor, and industry are essential, and need to be improved;
   - Legal divisions of labor in transport activities are a barrier to improved productivity;
   - Federal legislation enacted to protect employment as a condition for receipt of government funds needs reconsideration;
   - Improved productivity may be achieved through standardization and pooling of equipment;
   - Intermodal transportation companies and consolidation of railroad companies offer improved productivity.

5. Forecasting Spatial-Distribution Interactions: Improvement requires that a conceptual framework needs to be developed to accommodate the diverse elements of the system. An improved modeling effort is one approach; a second step is the acquisition of appropriate data;

and a third step is to prepare and support researchers trained in the social sciences, engineering, management, planning and policy sciences to help implement this program.

The committee desires to point out again to the reader that the results of its freight system study are reported in four publications. A very comprehensive treatment of the factors involved in changes to motor carrier economic regulation was recorded in 1978 in the proceedings of a workshop, "Motor Carrier Economic Regulation." The long-term (15 to 20 years ahead) demand for total, and individual commodity, freight movement was explored extensively in research papers and discussions and reported in 1979 in the proceedings of a workshop, "Forecasts of Freight System Demand and Related Research Needs." The major issues and problems involved in improving the freight system, and the results of an evaluation of the potential, that is the possibilities, for improvement were discussed and recorded in 1979 in the report "A Review of the U.S. Freight system, Phase I Report, Possibilities for the Future." Detailed examples and explanations related to the problems identified and possibilities for improvement are contained in these previous reports. In this Phase II report brief discussion of recommendations is included, with mention of examples, but the reader is referred to the previous reports for any additional detail desired.

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