TRANSPORTATION RESEARCH RECORD 984

Economic Analysis of Transportation Investments and Economic Development

TRB
TRANSPORTATION RESEARCH BOARD
NATIONAL RESEARCH COUNCIL
WASHINGTON, D.C. 1984

Transportation Research Record 984
Price $10.80
Editor: Elizabeth W. Kaplan
Compositor: Lucinda Reeder
Layout: Marion L. Ross

modes
1 highway transportation
2 public transit
3 rail transportation
4 air transportation
5 other

subject area
15 socioeconomics

Transportation Research Board publications are available by ordering directly from TRB. They may also be obtained on a regular basis through organizational or individual affiliation with TRB; affiliates or library subscribers are eligible for substantial discounts. For further information, write to the Transportation Research Board, National Research Council, 2101 Constitution Avenue, N.W., Washington, D.C. 20418.

Printed in the United States of America

Library of Congress Cataloging in Publication Data
National Research Council. Transportation Research Board.
Economic analysis of transportation investments and economic development.

(Transportation research record; 984)
1. Transportation–Congresses. I. National Research Council (U.S.). Transportation Research Board. II. Series.
TE7.H5 no. 984 [HE11] 380.5 s [380.5'9]
85-4981 ISBN 0-309-03768-9 ISSN 0361-1981

Sponsorship of Transportation Research Record 984

GROUP 1–TRANSPORTATION SYSTEMS PLANNING AND ADMINISTRATION
Kenneth W. Heathington, University of Tennessee, chairman

Management and Finance Section
William A. Bulley, H. W. Lochner, Inc., chairman

Committee on State Role in Waterborne Transportation
Norman B. Wolf, Illinois Department of Transportation, chairman
C. Neil Davis, Arlene L. Dietz, Samuel Ewer Eastman, John R. Fisher, Herbert R. Haar, Jr., Paul C. Heitmann, Lowell D. Hill, Don H. Jones, James H. Kellow, Paul R. Lowry, W. Sam Masters, Charles O. Meiburg, M. William Newstrand, Donald E. Poling, Peter L. Shaw, Stephen Thorp, Stanley L. Vale, James E. Vitale, Larkin Warner

Social, Economic and Environmental Factors Section
Kathleen E. Stein-Hudson, New York City Department of City Planning, chairman

Committee on Application of Economic Analysis to Transportation Problems
Gary R. Allen, Virginia Highway and Transportation Research Council, chairman
Antoine G. Hobeika, Virginia Polytechnic Institute and State University, secretary
Hayden Boyd, Kenneth L. Casavant, Yupo Chan, Steven B. Colman, Charles W. Dale, Ralph C. Erickson, Michael D. Everett, Z. Andrew Farkas, Chris Hendrickson, Loyd R. Henion, Andre Kimboko, Douglass B. Lee, Jr., William F. McFarland, Douglas S. McLeod, Jeffery L. Memmott, Alan D. Pearman, Gabriel J. Roth, Ralph D. Sandler, Fred Lee Smith, Jr., John C. Spychalski, Martin M. Stein, Wayne K. Talley, Willard D. Weiss, Mark J. Wolfgram

Committee on Economic Development of Land and Transportation Systems
William C. Habig, Mid-Ohio Regional Planning Commission, chairman
Harry B. Caldwell, Federal Highway Administration, secretary
Steven F. Bloomfield, Robert J. Harmon, William S. Herald, Lance A. Neumann, Thorold S. Smith, Jr., Gary S. Spivack, Wilbur A. Steger, Paul L. Verchinski, Arthur L. Webster II, Edward Weiner, Phillip B. Whitmore

Public Transportation Section
John J. Fruin, Port Authority of New York and New Jersey, chairman

Committee on Intercity Bus Transportation
Ray A. Mundy, University of Tennessee, chairman
Frederic D. Fravel, North Carolina Department of Transportation, secretary
John S. Andrews, Eugene D. Arnold, Jr., Lawrence F. Cunningham, Donald L. Dean, John F. Di Renzo, Marta V. Fernandez, E. Brinkley Garner, T. C. Knappen, Dennis H. Moore, Harold E. Morgan, Barry B. Myers, Paul A. Nagle, Jerome J. Rudnick, Norman R. Schneider, Robert E. Stammer, Jr., Kathleen E. Stein-Hudson, Sheldon G. Strickland, William C. Underwood, Thomas Urbanik II, John A. Walgreen, Kenneth A. White

Kenneth E. Cook, Transportation Research Board staff

Sponsorship is indicated by a footnote at the end of each paper. The organizational units, officers, and members are as of December 31, 1983.

Contents

Addresses of Authors

Butler, Stewart E., Transportation Systems Center, U.S. Department of Transportation, Kendall Square, Cambridge, Mass. 02142

Button, K. J., School of Economic Studies, University of Leeds, Leeds, West Yorkshire LS2 9JT England

Cherwony, Walter, Abrams-Cherwony & Associates, PSFS Building, Suite 3139, 12 South 12th Street, Philadelphia, Pa. 19107

Denham, Edward T., Florida Department of Transportation, 605 Suwannee Street, Tallahassee, Fla. 32301

Frank, Stephen, Maryland Department of Transportation, P.O. Box 8755, Baltimore Washington International Airport, Md. 21240

Gazda, Walter E., Transportation Systems Center, U.S. Department of Transportation, Kendall Square, Cambridge, Mass. 02142

Horn, Richard J., Transportation Systems Center, U.S. Department of Transportation, Kendall Square, Cambridge, Mass. 02142

Ismail, Hilmy, OAO Corporation, 7500 Greenway Center Drive, Beltsville, Md. 20705

Lemmerman, John H., New York State Department of Transportation, State Campus, 1220 Washington Avenue, Albany, N.Y. 12232

Mahmassani, Hani S., Department of Civil Engineering, University of Texas at Austin, Austin, Tex. 78712

McLeod, Douglas S., Environmental Science and Engineering, Inc., P.O. Box ESE, Gainesville, Fla. 32602

Pearman, A. D., School of Economic Studies, University of Leeds, Leeds, West Yorkshire LS2 9JT England

Rogers, Gordon A., Forest Products and Construction Material, Canadian National Railways, Montreal, Quebec H3B 2M9 Canada

Sandler, Ralph D., Florida Department of Transportation, 605 Suwannee Street, Tallahassee, Fla. 32301

Schonfeld, Paul, Civil Engineering Department, University of Maryland, College Park, Md. 20742

Shaw, Peter L., Institute for Transportation Policy and Planning, Center for Public Policy and Administration, California State University, Long Beach, Calif. 90840

Smith, Rene T., Transportation Systems Center, U.S. Department of Transportation, Kendall Square, Cambridge, Mass. 02142

Stevens, Albert M., Transportation Group, University of New Brunswick, Fredericton, New Brunswick E3B 5A3 Canada

Talley, Wayne K., Department of Economics, Old Dominion University, Norfolk, Va. 23508

Toft, Graham S., Institute for Interdisciplinary Engineering Studies, Purdue University, West Lafayette, Ind. 47907

Trickey, Jack, Florida Department of Transportation, 605 Suwannee Street, Tallahassee, Fla. 32301

Webster, Arthur L., EXP Associates, Inc., 8302 Westmont Terrace, Bethesda, Md. 20817

Wilds, Marcia C., Potomac-Electric Power Co., 1900 Pennsylvania Avenue, N.W., Washington, D.C. 20006

Wilson, Frank R., Transportation Group, University of New Brunswick, Fredericton, New Brunswick E3B 5A3 Canada

Effects of U.S. Rail Deregulation on Pricing Activities of Canadian Railroads

FRANK R. WILSON, GORDON A. ROGERS, and ALBERT M. STEVENS

ABSTRACT

The U.S. Congress, in an effort to assist the country's railroad industry that was suffering from a restrictive and outdated regulatory system, passed legislation aimed at revitalizing the troubled industry. In passing the Staggers Rail Act of 1980, Congress introduced deregulation to the railroads, granting them the freedom that allowed them to operate in a more competitive environment. The revised regulatory structure has had widespread implications for the pricing strategies of both U.S. and Canadian railroads. The effects of the U.S. rail deregulation on the pricing activities of both U.S. and Canadian railroads are examined in this paper. The railroad industry in Canada had operated under considerable price freedom since the National Transportation Act was passed in 1967. U.S. railroads, in comparison, appeared to be overregulated and increasingly unable to compete with other modes of transportation. Legislation passed in the 1970s was unsuccessful in creating the stimulus the railroads required. The Staggers Act did indeed relax many of the rail carriers' obligations, but it also drastically curtailed the degree of antitrust immunity the industry had enjoyed for many years. The railroads have been forced to operate in a much more competitive manner since October 1980, and contracts and rebates are becoming commonplace. The Canadian railroads have been forced to respond to the revival of competition south of the border or risk losing a significant proportion of their international traffic. Deregulation has also had legal ramifications for Canadian carriers because the laws governing the movement of freight traffic in the two countries are now in conflict. There is a distinct possibility that the Canadian railroads will lose their immunity to anticombines laws, an event that has already occurred in the United States.

The Staggers Act has created conflict between Canadian and U.S. railroad regulations in a number of areas. In this paper the major differences in the legislative framework of the two countries and how these differences have affected the pricing of international freight traffic originating in Canada are examined. Three major areas are examined: (a) the Canadian railroads' response to American competition and price freedom; (b) complications of participation in through rates and routes because of surcharges, cancellations, and rebates; and (c) antitrust implications of deregulation for Canadian railroads.

CANADIAN RAILROAD PRICING SINCE U.S. DEREGULATION: A CASE STUDY

Changes in pricing policies since U.S. deregulation have not been limited to U.S. railroads. Canadian carriers have been forced to take action of a competitive nature to avoid a significant erosion of their market share of U.S. traffic. Shortly after the Staggers Act was passed in October 1980, U.S. railroads began an overhaul of their freight rate structure that resulted in many rates being reduced. A significant number of these rate reductions applied to points in Canada served by a U.S. carrier or to border points that could easily be reached by a Canadian shipper.

Canadian railroads were then faced with a situation where many origins they served had published rates that were lower than their own if the traffic was routed on a U.S. carrier that had filed an independent tariff. In order to protect their share of international traffic, Canadian railroads were forced to publish competitive rates. It was assumed that this competition would be beneficial to shippers; however, such was not necessarily the case. The reasons will become clear from the following case study.

The British Columbia forest industry is heavily dependent on the United States as a market for its products. Of the 8.9 billion board feet (fbm) of lumber exported from British Columbia in 1980, 6.3 billion fbm, or 71 percent, went to the United States (J.G. Black, "Impact of U.S. Rail Deregulation on the Forest Products Industry of British Columbia," paper presented to the Council of Forest Industries, Vancouver, British Columbia, October 6, 1981). Of that amount, 78 percent moved by rail. The distance from the source of production to the major consuming areas makes transportation costs a critical factor in the ability of British Columbia lumber producers to market their product competitively. For this reason the industry has been directly affected by U.S. rail deregulation, as well as by the Canadian response to the new environment.

This particular analysis includes a review of the traditional international freight rate structure and a discussion of new tariffs that have been brought into effect since deregulation. A summary of reaction from the industry to the breakdown of traditional rate relationships is presented.

The Transcontinental Freight Rate Structure

Lumber shipments by rail from British Columbia and the U.S. Pacific northwest have customarily moved under rates published by the Trans-Continental Freight Bureau (TCFB). These rate structures have been in existence for approximately 75 years and provide the basis for all transcontinental commodity movements originating in western Canada and the United States. The rates are based on origin groups, which are blanket zones covering large geographical areas. Rates from points within an origin group are identical, which has led to some interesting anomalies.

For example, the Coast Rate Zone, or group 1, extends from Prince Rupert, British Columbia, all the way down the west coast to the California border. Because all points in this group take the same rate basis, a shipper in Prince Rupert pays the same freight rate as a shipper in Portland, Oregon, 700 miles to the south.

The origin zones under the TCFB rate structure are shown in Figure 1. It is apparent that the rates in the Coast Zone were predicated on responding to potential water competition from the west coast to the east coast. The British Columbia Rail Rate Zone was established in the 1950s, long after the original TCFB rate structure. It reflects the degree of captivity of shippers along the line, and because there is no competition from water carriers, rates are somewhat higher than the Coast basis. The Interior and Inland rates were once higher than the Coast Zone rates; however, because water competition has diminished, the Coast rates are now generally higher than the Interior rates.

One of the functions of a rate bureau is to provide a forum for collective rate making and division hearings. Independent action by single carriers was traditionally unheard of and, until recently, unnecessary. The Staggers Act changed all that. Under U.S. rail deregulation, carriers are encouraged, indeed required, to take independent action on single-line rates. Collective discussion is no longer permitted because of the extended application of antitrust laws. At the same time, a number of U.S. railroads were embarking on ambitious acquisition programs that facilitated the development of single-line through rates.

Competitive Railroad Action

Taking advantage of the deregulated environment, the Burlington Northern (BN) substantially lowered its rates on lumber from Washington and Oregon to points in Southwestern Lines territory. Included in this reduction were points in British Columbia served by the Burlington Northern--specifically Vancouver and Nelson, a town in the southern interior just north of the U.S. border. The new rates resulted in reductions of up to $1,400 a carload on lumber from Vancouver to Dallas, Texas, a city at the center of one of the fastest growing markets for lumber.

The new rates lowered transportation costs by up to $21 per thousand board feet from Vancouver. This is equivalent to a 25 percent reduction. The magnitude of this reduction was sufficient to divert a substantial amount of lumber traffic normally handled on Canadian railroads to a U.S. carrier. Canadian railroads were not slow in responding to this

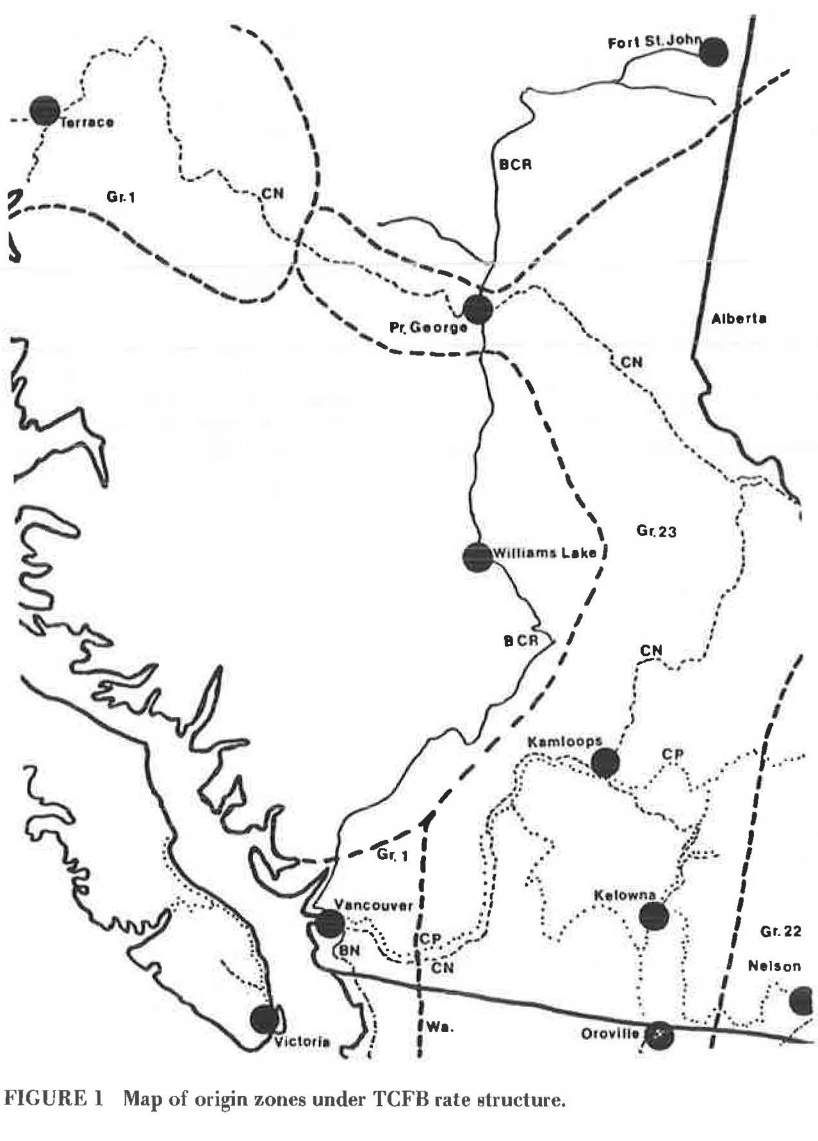


FIGURE 1 Map of origin zones under TCFB rate structure.

threat. Within weeks of the publications of the BN tariff, both Canadian National Railways, through the Canadian Freight Association (CFA), and Canadian Pacific West (CPW) issued tariffs that contained rates structured to minimize any erosion of market share. A comparison of the rates published in these tariffs, as well as those in the BN and TCFB tariffs, is given in Table 1.

TABLE 1 Comparison of TCFB and Special Rates to Dallas[a]

Origin	TCFB 4518 ($)	BN 4494 ($)	CFA 4105[b] ($)	CPW 4025[b] ($)
Vancouver	5,731	4,323	5,115	4,771
Terrace	5,731	–	5,340	–
Portland, Oreg.	4,746	4,323	–	–
Prince George	5,621	–	5,230	–
Kamloops	5,621	–	4,955	4,837
Kelowna	5,621	–	4,955	4,579
Nelson	4,467	3,960	–	3,976
Oroville, Wash.	5,621	3,960	–	–
Williams Lake	6,072	–	5,450	–
Ft. St. John	5,775	–	5,450	–

Note: Dash = not applicable.
[a]Based on 110,000 lb per car.
[b]As of January 1, 1982.

The overall result of this rate action was a major reduction in freight rates on lumber from points in British Columbia to destinations in Texas. It would have appeared that these reductions would be welcomed by the industry. This was not the case. If there is anything the lumber industry resists more than a rate increase, it is a restructuring of rates that alters existing rate relationships between mills. Therefore, although the new tariffs reduced the rates from all British Columbia origins to Texas, they lowered rates from some origins more than from others. The result was a distortion of the traditional rate relationship that had existed between mills throughout the province. The former rate structure tended to minimize factors such as distance and cost in the rate, resulting in a variation in freight rates of only about $100 per car on Canadian National Railway origins. This rate scale allowed mills in the northwestern area of the province to remain competitive, on the basis of transportation costs, with mills located in other areas of the province much closer to the market.

Deregulation in the United States brought the traditional rate structure to an end. The rates published by CN and CP in their respective tariffs were based on meeting the competition from U.S. carriers, and therefore the distance factor could no longer be ignored. Although rates from all origins throughout the province were reduced, those geographic points considered most vulnerable to U.S. competition benefited the most.

Reaction of Shippers

Major protests against the new rate structure came from producers in the northwest corner of the province. The parity that formerly existed between this area and other parts of the province was removed under the new, competitive rate structure. If producers in this area were forced to pay freight rates based on cost- and distance-related factors, their ability to compete with southern British Columbia producers would be considerably eroded. Reaction from the producers in this area was swift. Representatives of mills attempted to point out the effects on their operations that would result from the newly implemented rate structure. A summary of their concerns follows.

1. Traditional rate relationships have been disrupted so the net effect is that northwestern British Columbia mills are now at a rate disadvantage compared to Vancouver and Prince George mills.
2. These transportation penalties, unless rectified, will cause further deterioration of the northwestern mills' ability to compete effectively in the North American markets.

Although the overall reduction in freight rates was acknowledged, the mills' concerns were the result of some of their competitors' rates having been reduced even further.

Matters of this type also normally involve the Transportation Committee of the British Columbia Council of Forest Industries (COFI). Comprised of representatives of most companies in the British Columbia forest industry, the Council is a body whose aim is to present a unified viewpoint on areas of concern to members. U.S. rail deregulation and its effects on the British Columbia forest industry are a matter that clearly has varying ramifications for different members of the industry. Although deregulation is proving to be beneficial to some members of the industry, the protest noted previously indicates that it may be difficult for the Council to maintain unanimity in its negotiations with the railroads. In its 1981-1982 annual report the Council acknowledges that

> One result of deregulation is the gradual breakdown of traditional rate relationships and parity. In response to this situation, the Transportation Committee has been considering a proposal to restore some sort of rate structure that would reflect to a certain extent competitive factors, location, and historical rate relationships. This process is underway with all sectors of the British Columbia forest industry considering various proposals. Without such a structure, it is expected that traditional rate-making practices would completely break down, and many sectors of the forest industry would suffer (1,p.12).

This statement correctly identifies the problem but not the solution. It is correct in its assertion that traditional rate-making practices have probably come to an end, but, although a new rate structure will indeed be based on competitive factors and location, it is unlikely that historical rate relationships will play a significant role in the new era. The number of blanket zones taking the same rate is likely to diminish. The new structure will likely cause greater emphasis to be put on a producer's locational advantage, a factor that the traditional rail freight rate structure minimized. The long-term outcome of the restructuring of rates may well be an overall adjustment of current marketing strategies by shippers who may find that certain markets become inaccessible to them if their product is transport-cost sensitive.

JOINT INTERNATIONAL TARIFFS

One of the casualties of the Staggers Act was the method by which shippers were kept informed of changes in rates and routes. Before deregulation, for any given origin and destination pair, there was usually only one rate charged regardless of the route the car was shipped on. This system did not provide much incentive for rate competition between carriers although service was used as a means to solicit traffic. The situation was also less complicated for the traffic manager because any rate changes made were applied equally by all carriers serving the territory. Finally, rate bureaus, by approving all rate changes and overseeing publication of all tariff supplements, ensured uniform knowledge of tariffs throughout the industry.

The Staggers Act changed these procedures. By stripping rate bureaus of much of their authority and allowing carriers to take independent action through surcharges or route cancellations, the U.S. Congress changed the rules of operation. In their drive to encourage competition in the railroad industry, the legislators created considerable confusion. It is now extremely difficult for both shippers and carriers to be fully aware of what rates are available on a particular route. The issue has been further complicated by the growth of contract rates with confidential rebates. The result is that no one, other than the parties directly involved, knows the effective rate being paid for a particular service.

The new U.S. legislation creates further difficulties for Canadian railroads because it conflicts with a number of provisions of Canadian railway law. For example, when a U.S. carrier surcharges its portion of a joint international route, Section 286 of the Canadian Railway Act requires that the surcharge be filed with the Canadian Transport Commission (CTC) because the surcharge affects an international tariff. Furthermore, a Canadian carrier is permitted to collect only those rates that have been filed with the CTC. After the passage of the Staggers Act, it was observed that a number of U.S. carriers were surcharging their portion of an international movement but were not notifying other carriers and were not filing the surcharge with the CTC. This situation made it difficult for Canadian carriers originating the international traffic to quote the correct rate to the shipper, and even more difficult to collect the full transportation charge, because the entire amount had not been filed with the CTC. After receiving a number of complaints from shippers paying more than they anticipated on a cash-on-delivery shipment, the Canadian railroads notified their U.S. counterparts that they "were unwilling and unable to collect their surcharges and we suggested that they collect these surcharges at their own stations" (J.L. DiFruscia, "U.S. Rail Deregulation Update," paper presented to the Council of Forest Industries, Vancouver, British Columbia, October 6, 1981, p. 8).

Another provision of the Staggers Act that comes into conflict with the Railway Act is Section 208--Contracts. By permitting rebates on both interstate and international movements, the Staggers Act is in direct conflict with Section 380 of the Railway Act, which states explicitly that rebates are illegal in Canada because railways cannot receive nor can shippers pay anything other than the published rate in the tariff. U.S. contract legislation is also in conflict with Section 286 of the Railway Act, whereby a joint international tariff must be filed in its entirety with the CTC.

An example of some of the problems faced by Canadian carriers under the conflicting legislation is given in the following scenario. A shipper in Canada is quoted a rate from the joint international tariff for a move from a western Canadian origin to Chicago. The shipper is then approached by one of several U.S. carriers who provide service on the Duluth to Chicago portion of the route. The U.S. railroad offers the Canadian shipper a discount on the through rate if the car is routed on his road. This may take place without the knowledge of the Canadian carrier. A second Canadian shipper, competing with the first for the Chicago market, discovers it is losing business because it can no longer compete with the shipper receiving a rebate. The U.S. carrier may be unwilling to give the second shipper the same rebate the first receives because the second shipper cannot guarantee the same volume.

The second shipper, who feels discriminated against, may appeal to the CTC under Section 23 of the National Transportation Act. The likely outcome would be the enforced cancellation of all joint international rates, to be replaced by proportional rates to the border. Carriers south of the border would be free to deal with Canadian shippers on a contractual basis as long as there was no participation by Canadian railways.

The deregulated U.S. environment results in a confusing array of rates and routes for traffic managers to analyze. Managers have to determine which routes on an international move are higher than the published rate because of surcharges, which are lower because of rebates, and which may have been cancelled altogether. The ability of producers to maintain their competitive positions in certain U.S. markets will depend on their aptitude for searching out the most efficient and economical route to that market. The proportion of rail transportation cost in a product's delivered price will be subject to wide variation, depending on the traffic manager's ability to negotiate freight rates.

ANTITRUST IMPLICATIONS FOR CANADIAN RAILROADS

Perhaps the greatest impact felt by the Canadian railroads and shippers as a result of the Staggers Act is in the area of antitrust law. The Reed-Bulwinkle Act of 1948 protected members of the U.S. rate bureaus from the provisions of the Sherman antitrust laws. Because Canadian railroads were parties to the bureaus, they were indirectly afforded the same protection. Under Canadian railway legislation, rail carriers are permitted, and in some cases compelled, to set rates jointly without violating anticombines law.

Section 219 of the Staggers Act, which restricts the activities of rate bureaus, has cast a shadow of doubt over the practices of Canadian railroads in setting international rates. To fully appreciate the dilemma that now exists, three aspects of the problem need to be understood:

1. The extraterritorial application of U.S. antitrust law,
2. The effects of such application on the rate-making practices of Canadian railroads, and
3. The response of Canadian railroads and shippers to the cancellation of antitrust immunity.

Extraterritorial Application of U.S. Antitrust Law

The first question that comes to mind when discussing U.S. antitrust laws is why Canadians should be concerned about them at all. It would appear to be a logical conclusion that commercial activity that takes place entirely in Canada among non-U.S. citizens be subject to Canadian, not U.S., legislation. Considering that the Canadian transportation industry generally operates entirely in Canada, it would appear somewhat presumptuous of the United States to impose its laws on the commerce of Canada.

The simple answer to this question is that the U.S. antitrust laws are extraterritorial in scope. Actions taken in a foreign country may be within the scope of the antitrust laws where the effect of the activity is felt on import commerce into or export commerce out of the United States (J.W. Ongman, "U.S. Anti-Trust Ramifications for the Canadian Transport Industry," paper presented to the Canadian Transportation Research Forum, 1982, p. 5). Considering that between 25 and 35 percent of Canadian railroads' revenues are derived from transborder traffic, a major portion of the industry could conceivably come within the scope of U.S. antitrust legislation. The acid test for jurisdictional reach is whether the consequences of any discussion will have an effect on U.S. consumers. Considering the proportion of transportation costs in a Canadian commodity's U.S. delivered price (more than one-third in some cases), there is little doubt that the criteria for application have been met.

The issue of extraterritorial application is not a recent development by any means, and the principle extends beyond the transportation industry. In the 1945 case, U.S. v. Aluminum Co. of America et al., the Supreme Court held that a cartel scheme entirely among non-American firms and operating in Europe would fall within the jurisdiction of the U.S. Sherman Act if the scheme's intent were to restrain trade in the United States. The court left no doubt as to its opinion by stating that U.S. laws have jurisdiction over foreign corporations irrespective of whether such corporations' actions are contrary to their own government's commerce legislation.

This brief discussion of U.S. jurisprudence and its extension to non-U.S. citizens underlines the quandary that Canadian railroad pricing officers have found themselves involved in since the passage of the Staggers Act. If they protect themselves from the new U.S. legislation, Canadian railway personnel are unable to abide by the Canadian Railway Act and Transport Act, which requires joint consultation on all traffic from competitive points. Although joint rate making continues on domestic traffic, discussion of international rates among Canadian carriers has been abandoned.

Effects on Pricing Activities

When an industrial sector the size of the railroads has operated under a particular set of circumstances for more than a century, the transition to an entirely new legal structure is not easy. In deciding how to respond to the antitrust dilemma, Canadian railroad officials asked themselves two questions:

1. Do the U.S. antitrust laws indeed apply to the Canadian railroads?
2. Assuming they do, and until such an issue is resolved, which activities are still considered legal and which are thought to be in doubt?

The termination of antitrust immunity with regard to international traffic was completely unanticipated by all parties affected. The policy of Canadian railroads was and still is that collective rate making is "absolutely essential to the efficient transfer of goods by rail from Canada to the United States, and has been viewed as an essential mechanism for reconciling the transportation policy of Canada with that of the United States" (comments of Canadian Railroads before the Interstate Commerce Commission, November 26, 1980, p. IV-12).

The curtailment of rate bureau immunity combined with the extraterritorial application of U.S. antitrust laws has created an entirely new set of complications for the Canadian railroad industry. It has contributed to consternation among pricing officials who find themselves forced to obey two conflicting sets of rules. It has hampered negotiations with U.S. carriers who are reluctant to participate in any activity that could be construed as a violation of the antitrust laws. The eventual outcome may be the gradual erosion of international through rates, their replacement by proportional rates to the border, and higher total freight rates.

REACTION OF THE CANADIAN TRANSPORTATION INDUSTRY

When the laws of one country are suddenly applied to activity that is conducted in another country, a vigorous protest from the latter is to be expected. When it became clear that the combined effect of the Staggers Act and the Interstate Commerce Commission (ICC) 5b Decision would be the abrogation of antitrust immunity for all international traffic, reaction from the Canadian shipping and transportation community was swift.

Submissions were made to the ICC by both major Canadian railroads, the government of Canada, and various shipper organizations. Shortly after the passage of the Staggers Act, Canadian National and Canadian Pacific Railroads make a joint presentation to the ICC; that presentation included testimony of senior marketing officers of each company as well as that of independent, expert witnesses. In his remarks to the Commission, R.C. Gilmore, Vice President, Marketing and Sales, CP Rail, outlined the implications of the rescission of antitrust immunity for Canadian railroads:

> The vast preponderance of Canadian railroads' traffic base consists of basic bulk commodities which are shipped from a number of geographically disperse origin points to an even larger number of destination points. The transportation realities of these commodities cannot be well served by point-to-point rates. Rather, rate groupings with inherent rate relationships are required in order to permit these commodities and the shippers of these commodities to compete in the destination markets. However, if antitrust immunity for collective actions is revoked the railroads will be powerless to prevent the dissolution of these rate structures (C.S. Stark, "A View of Current International Anti-trust Issues," paper presented at World Trade Institute Seminar on Advanced International Anti-trust Practices and Related Trade Issues, May 20, 1982, p. 35).

In their presentations both CN and CP reiterated the benefits of collective negotiation for both shippers and railroads. They pointed out the consequences for shippers with plants located in geographically remote areas who would find themselves increasingly disadvantaged in the destination markets as traditional rate structures broke down.

The underlying emphasis throughout the submission by the railroads was on the disruptive effect of the termination of antitrust immunity on the carriers, the shippers, and the market. Although the presentations successfully demonstrated the consequences for Canadian producers and railroads, there was little evidence in the presentations to indicate the potential adverse impact on the U.S. consumer. Because the consumer is the one with whom the legislators and administrators are most probably ultimately concerned, unless it can be clearly demonstrated that the new regulatory structure will have a negative effect on this sector of the economy, it is doubtful that the Commission's decision will be altered. The ICC does not concern itself with the plight of producers in remote areas of Canada who can no longer compete in certain markets in the United States.

It is unlikely that the decision to revoke antitrust immunity from collective rate making will be changed to protect the U.S. consumer. It is likely that there will be significant disruption in international commerce, that traditional rate structures will be eroded, and that some producers may suffer. If the overall effect of increased competition is perceived to benefit the U.S. consuming public, any pleas from affected Canadian concerns will most probably be ignored.

CONCLUSION: WHITHER COLLECTIVISM?

The underlying theme of this paper has been a comparison of the Canadian and U.S. systems of railroad regulation and a discussion of how recent changes in the latter have influenced activities in the former. The issues are complex and the ramifications are widespread, but they can be summarized as follows.

1. The Canadian regulatory structure, basically unchanged since the National Transportation Act was passed in 1967, has allowed railroads considerable pricing freedom and has contributed to a financially strong and competitive Canadian railroad industry.
2. U.S. railroads, in contrast, were overburdened by an outmoded regulatory framework and found themselves hampered by regulations that were causing them to lose more and more traffic, contributing to a serious deterioration of the country's entire railroad industry.
3. As a result of pressures to save the industry from total bankruptcy, and coinciding with a general trend toward deregulation of U.S. industry, the Staggers Rail Act of 1980 was passed granting virtually complete pricing freedom to railroads. The result was a move toward more innovative and competitive pricing schemes in the United States, a trend that affected the Canadian railroad industry as well.
4. Deregulation ended the antitrust immunity enjoyed by railroads operating through rate bureaus. The application of the antitrust laws was extended to all traffic terminating in the United States, even if it originated outside the country.
5. As a result of this extraterritorial application of U.S. antitrust law, collective rate making by Canadian railroads on international traffic is in jeopardy.

Rarely has a piece of legislation been passed in the United States that has had such significant implications for a Canadian industry, in both the pricing and the legal arenas. Canadian railroads have reacted to the new environment in a competitive manner, reducing rates where there was potential erosion of market share.

The complications caused by the antitrust laws, combined with the lack of support for rate bureau immunity from a number of Canadian shipper organizations, has probably had the most deleterious effect on rate-making practices in Canada. Although the future of collective rate making by the Canadian railroads is in some doubt, it is probably safe to assume that there will never be a return to the level of immunity that existed before U.S. deregulation. Canadian shippers indicate, however, that industry opinion regarding this matter is divided.

REFERENCE

1. Council of Forest Industries of British Columbia. Annual Report of the Northern Interior Lumber Sector, 1981/82. Victoria, British Columbia, Canada, March 1982.

Publication of this paper sponsored by Committee on Application of Economic Analysis to Transportation Problems.

Evaluation of FAA's Economic Analysis Guide

DOUGLAS S. McLEOD

ABSTRACT

FAA's 1982 "Economic Analysis of Investment and Regulatory Decisions--A Guide" was reviewed for its effectiveness in determining the economic desirability of aviation-related project investment and regulatory alternatives. The FAA Guide was found to be excellent because it is (a) a comprehensive tool for analyzing investment and regulatory alternatives, (b) based on sound transportation economic concepts, (c) direct in approach, (d) easily understood, (e) well organized, and (f) not likely to become outdated because updating procedures are provided. Major weaknesses are (a) unavailability of important references that are cited, (b) lack of examples to assist users' understanding, and (c) reliance on potentially numerous hand calculations. The FAA Guide recommends the treatment of intangible and quantifiable nonuser benefits and costs in the benefit-cost analysis; the reviewer, however, recommends that the benefit-cost analysis include only quantifiable aviation user benefits and project or regulatory costs.

In 1982 the Federal Aviation Administration (FAA) published Economic Analysis of Investment and Regulatory Decisions--A Guide (1), economic (benefit-cost) analysis guidelines for evaluating FAA's investment and regulatory decisions. In recent years, transportation agencies (e.g., AASHTO, UMTA, and FRA) have been providing guidance on applying economic analyses to transportation problems (2,3,4). The primary purpose of these guidelines is to assist the decision-making process by providing economic analyses of alternatives under evaluation and by determining the most economically efficient way to accomplish an alternative.

The purpose of this paper is to evaluate the strengths and weaknesses of the FAA Guide's organization and approach and to call attention to the Guide as a valuable tool. FAA regulations and investments involve millions of dollars; however, only rarely are major investment decisions subjected to rigorous economic analysis. In the first 2 years after the Guide's publication, no known major airport improvement has been evaluated using the methodology of the Guide. In this paper, perceived weaknesses of the Guide are emphasized for the benefit of current and potential users and in the hope that when the Guide is updated the points made here will be considered. The perceived weaknesses do not detract from the overall high quality of the Guide.

ORGANIZATION

Strengths

Overall, the Guide is well organized, well written, and concise. Together, these factors contribute to the Guide's excellent potential for use. The Guide's economic approach should be readily understood, regardless of the potential user's aviation or economics background.

The Guide is effectively organized into seven chapters following a logical sequence from an introduction and an overview of economic analysis to the core chapters dealing with estimation of aviation benefits and costs. Subsequent chapters deal with decision criteria, sensitivity analysis, and inflation. The Guide contains three appendices. Appendix B, Standardized Values, is three pages long and contains virtually all economic benefit dollar values needed for the economic analysis.

The writing style is simple, direct, and generally easy to understand; there are, however, exceptions. For example, the important sentence about the value of increased passenger demand benefits (1,p.3-20, paragraph 2, lines 1-4) may be confusing to many potential users. Such critical ideas should be repeated in different words, expressed as an equation, or illustrated by an example. References are handled well.

One of the outstanding aspects of the Guide is the conciseness with which economic analysis principles are handled. The "economic problem" and fundamentals of economic analysis are easy to understand. These topics are presented in a way that should not discourage layman users when they first attempt to use the Guide. Just enough economic theory is presented to give the approach credence without burdening the user. The Guide is neither too technical nor too general; an excellent balance, which gives the reader a satisfactory explanation of the procedures, has been reached.

The Guide is truly a guide for economic analysts rather than a cookbook to be followed. Standardized dollar values and basic steps are provided that should result in reasonable closeness in fit among different users. Yet there is ample flexibility for aviation planners and economic analysts to determine such important aspects as delay reduction and whether to aggregate or disaggregate aircraft types. The importance of using sensitivity analysis on important input values is emphasized. An associated attribute of the Guide is that if widely used by FAA and aviation analysts, it would become the standard methodology to determine economic impacts of investments and regulations. This uniform approach would assist in improving economic analysis of aviation-related investments and regulations and in comparing impacts nationwide.

Weaknesses

The analyst must rely on numerous outside essential noneconomic sources for input. Although these sources are properly referenced, as discussed later, some of them are not readily available.

The Guide implies but does not state either its purpose or what it provides. It would be desirable for the first section of the Guide to include a statement to the effect that this guide allows the user to address whether the benefits of aviation investments and regulations exceed the costs of producing those benefits. The first section should also include the ideas expressed in the second paragraph of the abstract of the Guide.

Although the Table of Contents is comprehensive, the lack of an index at times detracts from the Guide's usefulness as a quick reference or as a source for answers to specific questions. A glossary of key terms would be helpful. For instance, it would be helpful if the definition of the term "cost" (e.g., on p. 1-2 cost represents that which is foregone, and on p. 4-1 cost represents resources consumed) and the discussion of whether the term "passengers" does or does not include crew members were in one section of the Guide.

A major fault of the Guide is that is provides few examples of how it can be used. Two comprehensive examples of the Guide's approach to evaluating regulations or investments would greatly assist potential users' understanding.

GENERAL APPROACH

Summary

The Guide presents an informative, eight-step, economic analysis process:

1. Define the objective,
2. Specify assumptions,
3. Identify alternatives,
4. Estimate benefits and costs,
5. Describe intangibles,
6. Compare benefits and costs and rank alternatives,
7. Perform sensitivity analysis, and
8. Make recommendations (1,p.2-4).

The Guide's economic analysis process is illustrated in Figure 1. The text of the Guide deals primarily with step 4 (estimating benefits and costs). Steps 6 and 7 also receive considerable treatment. Steps 1, 2, 3, 5, and 8 are addressed only briefly.

The Guide recommends a willingness-to-pay evaluation approach and recognizes three primary areas in which FAA investments and regulations generate benefits:

1. Safety improvement;
2. Capacity increases and delay reductions that can be further broken down into (a) aircraft operat-

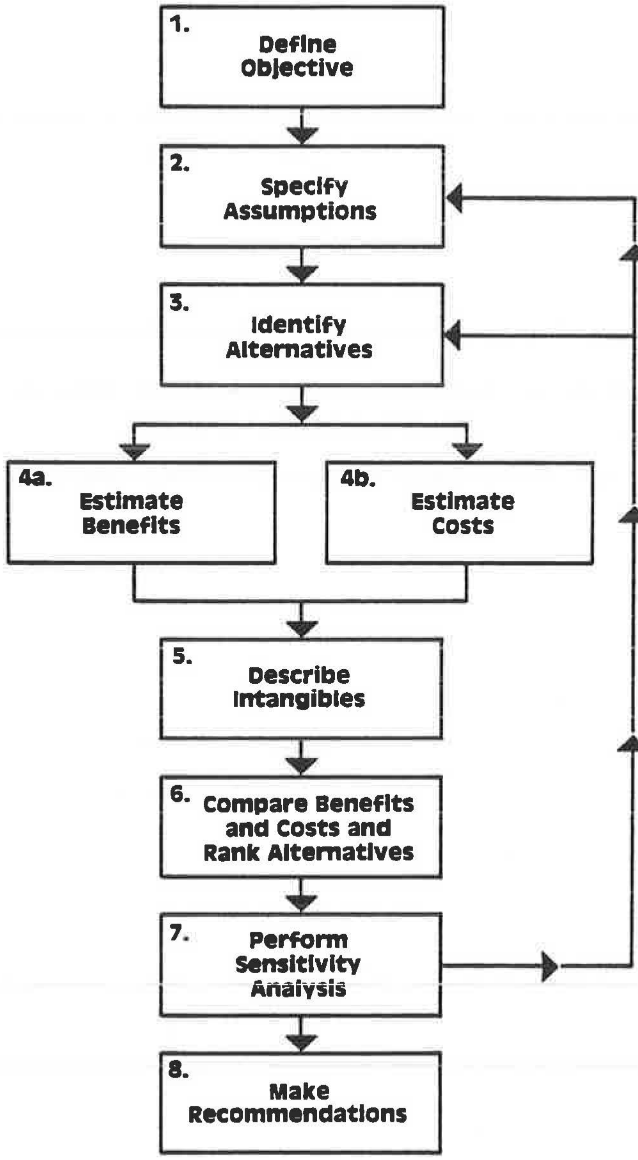


FIGURE 1 Economic analysis process.

ing expense reductions and (b) reductions of passengers' wasted time; and

3. Cost savings (e.g., increased employee productivity).

Other benefits (e.g., noise reduction) are also presented.

A life-cycle cost approach is proposed in which the total cost to the government and public of establishing and operating or complying with an investment project or regulation is included. Costs are grouped in four major categories:

1. Research and development costs,
2. Investment costs,
3. Operation and maintenance costs, and
4. Termination costs.

The Guide recommends use of the net present value criterion to evaluate the economic desirability of alternatives and sensitivity analyses of key input parameters.

Strengths

Although the Guide presents no innovative approach, it is an important contribution to transportation economics literature because of its potential use on a wide variety of aviation-related questions and its reliance on sound economic theory.

The Guide's willingness-to-pay approach is consistent with the majority of transportation and nontransportation economic thought. The dollar values used are obtained from a comprehensive 1981 FAA study (5) and represent dollar amount estimates of what society and users should be willing to pay for a specific benefit (e.g., the perceived benefit of preventing an aviation fatality).

Weaknesses

The Guide appears to be in agreement with the predominant position that all benefits and costs should be calculated to whomever they accrue. For example, the Guide states that "any [economic] analysis, of course, should include all known benefits whether or not they can be classified in the three main categories" (1,p.3-26)--safety, capacity increases and delay reduction, and cost savings--that can typically be expected to flow from FAA investment and regulatory activities. Three examples of additional benefits are presented: noise reduction, missed-approach benefit, and avoided-accident investigation costs. The Guide does not allude to nonproject-related costs (e.g., value of residential property located adjacent to a new airport).

Although the quantification of all benefits and costs associated with a proposed action is a noble and appealing goal for an economic analysis, this author (as well as other professionals) believes it is impractical. It is difficult enough to determine user benefits and project costs without expanding a benefit-cost analysis into such technical and pecuniary externalities as noise and other environmental pollution, residential and commercial property values, employment, airport sales, and wildlife kills. It is in these "other" quantifiable areas, as well as in the evaluation of intangible benefits and costs, that controversies over benefit-cost analyses most frequently occur.

The Guide conveniently mentions only one of many quantifiable nonuser benefits (noise reduction) or costs and then reverts in the remainder of the text to only a user analysis based on safety improvement, capacity increases and delay reductions, and cost savings.

The discussion of what benefits and costs should be included in an economic analysis would be much better if it were limited to user benefits and project costs, reflecting the predominant thought found in transportation economic studies. The question that this "user" economic analysis addresses is whether an investment or regulation is economically justified strictly on a transportation basis, not whether the proposed action is desirable for the whole social, economic, and environmental community. Nonuser and nonproject-related economic benefits and costs (e.g., property values and regional economics) would be better handled outside the benefit-cost analysis in the overall determination of the desirability of an alternative or a regulation. The Guide properly recognizes that, if these other benefits and costs are to be included, a range in dollars would be appropriate and such benefits and costs could be evaluated in the sensitivity analysis.

Two of the three examples of other benefits presented are actually elements of the Guide's three major benefit categories. The missed-approach benefit is an element of the capacity increases and delay reduction category, and the avoided-accident investigation costs are an element of the safety category. These elements should either be deleted or made part of the general categories. The missed-approach benefit should be an element of the Guide's approach because it relates directly to delay reductions, whereas the avoided-accident investigation costs should not because all other user dollar values of the Guide are derived from FAA's economic values document (5). If it is determined that avoided-accident investigation costs should be included in the determination of how much society is willing to pay to prevent accidents, those costs would be better handled in the economic values document (5) than in the Guide.

There may be some debate about whether step 5, describe intangibles, of the Guide's eight-step benefit-cost analysis process is indeed part of a benefit-cost analysis. Properly or improperly, these intangibles usually are treated outside the benefit-cost analysis, so that the benefit-cost analysis considers only quantifiable benefits and costs. However, the distinction between quantifiable and nonquantifiable benefits and costs and the ease or certainty with which dollar values may be placed on many benefits and costs are not clear.

Although the willingness-to-pay approach to determine benefits and costs predominates in the Guide, the Guide may have slipped into a resources-consumed approach in Chapter 4 on cost estimation (1,p.4-1). If benefits are perceived primarily as reductions in cost and a resources-consumed approach is used, many of the benefit values found in Appendix B would drop dramatically.

As do many economic studies, the Guide suggests that the values used represent minimum estimates of the dollar amounts society as a whole would be willing to pay for specified benefits. However, values that are conservative from one point of view can be exactly opposite from another point of view. If the values presented in Appendix B are indeed conservative, that implies society is not devoting adequate resources to meet aviation needs and the ranking of alternatives may not be accurate. The most realistic values, not conservative values, are needed. The Guide alludes to the proper use of realistic values instead of unduly high or low values in the judgmental accident evaluation subsection (1,p.3-12) and in the sensitivity analysis section; however, the Guide never formally states that realistic values are desired.

If a conservative approach to the evaluation of benefits is desired, the proper place to handle such an analysis is in the sensitivity analysis. Some analysts, however, may not find the Appendix B values conservative. For example, even after recognizing that air travelers do have higher incomes than automobile travelers, the Guide's value of time for air travelers of $17.50 per hour (1980 dollars) versus $2.40 per hour (1975 dollars) for highway users (2) might appear relatively high. The Guide's value to prevent a fatality is $530,000 (1980 dollars) compared with $190,000 (1981 dollars), as prescribed by the National Safety Council (6) for a highway death. Many state departments of transportation use the latter figure.

SPECIFIC APPROACH

Strengths

The Guide's specific approach is implicitly direct in estimating benefits and costs, comparing benefits and costs and ranking alternatives, and performing sensitivity analysis (steps 4, 6, and 7 of the Guide's eight-step economic analysis process). Safety, time, and operating benefits, the essence of the benefit analysis, are presented in fewer than 20 pages. Guidelines are provided for estimating the change in demand or increased passengers due to airport improvements.

The classification of cost components is detailed and helpful to a potential user. A brief discussion on cost concepts is provided that should prove helpful in understanding the multifaceted term "cost." The Guide pays proper attention to beginning-of-the-year, end-of-the-year, midyear, and continuous-compounding conventions in quantifying benefits and costs over time. It properly recommends that a midyear or continuous procedure be used.

Although, if done correctly, all benefit-cost analysis methods will yield the same ranking of alternatives, the Guide is consistent with most current economic thought in recommending the net present value method as the primary benefit-cost decision criterion. The Guide properly recognizes the importance of sensitivity analysis in the decision-making process to account for the imprecision and uncertainty that characterize most benefit-cost analyses.

Consistent with most other guidelines, the Guide recommends the use of constant instead of current dollars and that the constant dollars of the analysis year be selected as the unit of measurement. General and real inflation are handled properly. Price indexes are referenced, and procedures for updating all economic input values are addressed. Thus the Guide will not become outdated because of changing price levels.

Weaknesses

Although the Guide's approach to estimating benefits and costs appears simple and direct, the specific approach is never stated or illustrated. As long as all the steps are considered, results should be the same; however, confusion could exist about which step to perform first (e.g., should benefit values be updated before or after the dollar stream of benefits is calculated). Economic study features (i.e., discount rate, evaluation period, and study years) are treated in step 6 (comparing benefits and costs). These economic study features more properly belong in step 2 (specify assumptions). Similarly, cost updating procedures appear late in the text, but updating costs should be one of the first steps in estimating benefits and costs.

Adequate justification is given for the use of a 10 percent real discount rate, as prescribed by the U.S. Office of Management and Budget Circular A-94 (7) for federal programs and projects. However, many professionals (including this author) (2) believe that the 10 percent rate is unrealistically high for a real discount rate and that a more appropriate rate is from 4 to 7 percent. The effect of using a discount rate as high as 10 percent is to overrate projects with larger benefits in the near term and larger costs in the long term relative to projects with long-term benefits and short-term costs. Although perhaps locked into the 10 percent rate, specific reference to a sensitivity analysis of the discount rate would be appropriate.

Although updating procedures appear clear, no specific guidance is provided on how to update benefit values in Appendix B. However, FAA's updating methodology can be found elsewhere (5).

Replacement and restoration costs of damaged aircraft are given in Appendix B; however, no guidance is given on which cost category should be used or what percentage of aircraft accidents necessitates aircraft replacement. Guidance in this replacement/restoration area could be important in the evaluation of safety projects because restoration costs are one-third of replacement costs.

Although the section on capacity increases and delay reductions (1,p.3-13) details procedures on the impact of capacity increases on aircraft operating expenses and passengers' wasted time, it does not relate these increases to safety benefits. Furthermore, if one accepts the Guide's viewpoint that other benefits and costs should be included in the benefit-cost analysis, capacity increases would properly have a negative noise impact. The Guide addresses only effects of capacity increases on delay aspects rather than relating capacity increases to safety and, as appropriate, other impacts.

An alternative method of handling different numbers of operations with improvement and no-improvement assumptions is to use the average value of the operations of these two alternatives and calculate benefits on that average value. For instance, if the base case results in 20,000 operations a year and the improvement case results in 22,000 operations a year, the use of 21,000 operations a year in calculating benefits for both cases may be a worthwhile simplifying assumption.

As stated earlier, the Guide is not self-contained; the economic analyst must rely on outside sources to obtain such items as accident rates, air traffic demand, and cost estimates. This is one of the major drawbacks of the Guide. Sources of this crucial information are given, but many of them are not readily available if they are available at all. Therefore, the aviation planner or economic analyst is missing vital information and must rely on other data sources or professional judgments. Extensive reliance on judgment can cause significant variability in results. The Approach Aid Established Criteria Model, which is presented as "a comprehensive model for estimating safety and other benefits for approach and landing aids" (1,p.3-11), is unavailable. This model was not completed and draft material is not available for use. Without the model, the statement that "this [safety] subsection presents methodology for determining deaths, injuries, and damages prevented by risk reduction" (1,p.3-8) is not true. In the cost estimation section (1,p.4-8), the statement is made that "Guidance in preparing F&E [facilities and equipment] cost estimates for many established FAA projects in contained in F&E Cost Estimating Procedures and Summaries Handbook, FAA Order 6011.4, September 23, 1976" (1,p.4-8). However, when this author attempted to obtain a copy of the order to perform a benefit-cost analysis of improvement alternatives at a major air carrier airport, he was told that the order is for official FAA use only and is not available to the public.

In computing the present worth of an alternative, the Guide suggests its methodology must be applied to each year over the life of the capacity improvement (1,p.3-19). Because a computer model does not accompany the Guide, the calculation of benefits and costs on a yearly basis for an airport expansion project with five alternatives and a study period of 20 years would be cumbersome and subject to a high degree of error because of the number of calculations. The situation would be exacerbated if a 50-year capacity improvement life were used. An easier solution to this calculation problem is available, assuming a computer is not used and the stream of benefits or costs increases or decreases at an approximately equal annual percentage rate. The process is to calculate values for 2 years, one value associated with the first year and the other with later year, and use the procedure presented in A Manual on User Benefit Analysis of Highway and Bus-Transit Improvements, 1977 (2,p.30). For instance, if the cost benefit from a major airport improvement is $14 million the first year and $42 million the twentieth year, the stream of benefits over the 20 years with a 10 percent real discount rate can be readily calculated as approximately $180 million.

In a sensitivity analysis, the number of calculations increases dramatically, and a computer program is essential for multifaceted alternatives. Lack of a computer program may limit the Guide's use to relatively uncomplicated alternatives; however, this author has found it relatively easy to produce a computer program based on the Guide's methodology to handle major airport investment alternatives (8).

Although the Guide provides general guidance on parameters and the degree to which values should range in the sensitivity analysis, the Guide does not provide any specific guidance on appropriate ranges for benefit values. For instance, there may be differences of opinion about the value of travel time and what society is willing to pay to prevent a fatality. An analyst could vary the stated values by up to ±100 percent, as illustrated in the text, but values recommended by other sources or generated by other approaches (e.g., resources used versus willingness to pay) would be even more useful. A range of real discount rates (e.g., 4 to 10 percent) would also be desirable.

CONCLUSION

The FAA economic analysis guide is one of the best transportation economic guides published. It is based on sound transportation economic concepts and is generally easy to understand, direct in approach, and applicable to a wide range of aviation improvements and regulatory alternatives. The Guide's values can be readily updated. However, the Guide is heavily dependent on outside sources, some of which are referenced but not available, and lacks useful examples. The Guide's approach may result in a large number of hand calculations if the number of alternatives or years being evaluated is large and sensitivity analyses are desired. This author believes that the Guide should use a user benefit analysis approach rather than a more comprehensive approach encompassing all quantifiable and intangible benefits and costs. Overall, the Guide represents an important contribution to transportation economics literature, and, for better aviation-related decisions, its use should be encouraged.

REFERENCES

1. Economic Analysis of Investment and Regulatory Decisions--A Guide. Report FAA-APO-82-1. FAA, Washington, D.C., 1982.
2. A Manual on User Benefit Analysis of Highway and Bus-Transit Improvements, 1977. AASHTO, Washington, D.C., 1978.
3. Bus Rehabilitation Guidelines. UMTA; Battelle Columbus Laboratories and ATE Management and Service Company, Washington, D.C., 1983.
4. Benefit-Cost Guidelines: Rail Branch Line Continuation Program. FRA, Washington, D.C., 1980.
5. Economic Values for Evaluation of Federal Aviation Administration Investment and Regulatory Programs. Report FAA-APO-81-3. FAA, Washington, D.C., 1981.

6. Estimating the Cost of Accidents, 1981. National Safety Council, Chicago, Ill., 1982.
7. Discount Rates to be Used in Evaluating Time-Distributed Costs and Benefits. OMB Circular A-94. U.S. Office of Management and Budget, Washington, D.C., 1972.
8. FAA Based Benefit-Cost Computer Program. Environmental Science and Engineering, Inc., Gainesville, Fla., 1983.

Publication of this paper sponsored by Committee on Application of Economic Analysis to Transportation Problems.

Quick Benefit-Cost Procedure for Evaluating Proposed Highway Projects

JOHN H. LEMMERMAN

ABSTRACT

There has been a need within New York State's Department of Transportation to quickly evaluate proposed highway projects from an economic standpoint. The ability to do so would be a valuable tool for use in deciding which projects deserve further consideration in setting priorities. The procedure described in this paper is a quick method of estimating operating and travel time costs under before and after project conditions (the difference is an approximation of benefits to be derived). These benefits can then be compared with the project's estimated construction costs for an evaluation of the project's worth. Accident costs must be considered separately because they are site specific and difficult to generalize. This quick benefit-cost procedure can be applied to a variety of project types, including closed and posted bridges, highway resurfacing, and major reconstruction.

A number of methods are used to evaluate the worth of proposed highway projects. The methods range from major corridor analyses, which use elaborate and detailed computerized networks and programs that simulate traffic under a variety of conditions, for urban areas, to a "back of the envelope" calculation for a little-traveled rural facility. Within the New York State Department of Transportation (NYSDOT) there was a need for a quick method of determining whether a proposed project was economically feasible, apart from other considerations that might be used to evaluate its need or worth. Such a procedure could serve as a first-cut filter to either eliminate projects that do not meet some minimum benefit level or to alert the project analyst that, for a project to be feasible, additional considerations (economic, social, or political) must be taken into account.

In New York State a highway project proposal is submitted by a regional office in the form of a Project Initiation Report (PIR). This report contains a description of the problem along with background, forecasts, maps, proposed solutions, and project cost estimates. However, an estimate of benefits to be derived is usually not available. Therefore, the quick benefit-cost procedure presented here was developed to provide this important input at an early stage in the project evaluation process. David I. Gooding, Planning Division, NYSDOT, developed an unpublished package of ten tables documenting costs of the various components and the aggregate operating and total time costs of highway travel for automobiles and trucks from 1967 through 1981. The procedure provides a fairly comprehensive estimate of vehicle operating costs and time costs. Accident costs are not considered because they are site specific and not amenable to the types of generalizations that can be drawn concerning the other two classes of costs.

OVERVIEW OF QUICK BENEFIT-COST PROCEDURE

NYSDOT's Planning Division currently uses two highway user cost accounting programs in conjunction with its traffic simulation packages (1,2). Using the speed and congestion levels developed, the programs assign and summarize operating, travel time, and generalized systemwide accident costs. The quick procedure is a simplified manual version of this cost assignment process. It employs nomographs that can be entered with a minimum of information. To use this procedure, one needs only posted speed, average running speed, traffic with some estimate of vehicle mix, and highway section length for both the before and after conditions. Operating and travel time costs are calculated for both conditions and are then subtracted. The result can then be compared with the project costs by any of the various benefit-cost relationships.

In the nomographs (Figures 1-4), posted speed and average running speed are surrogates for facility

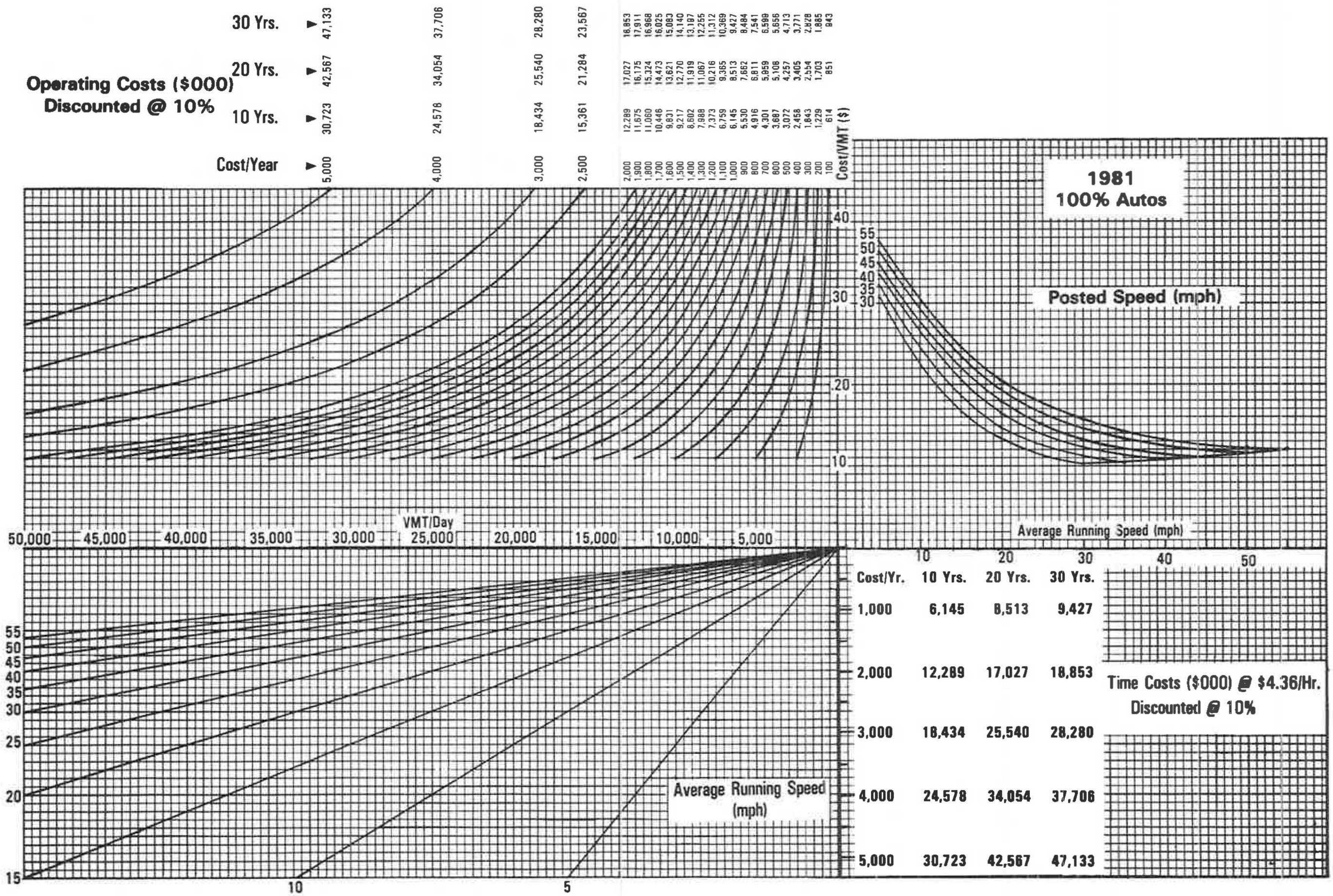


FIGURE 1 Nomograph for 100 percent automobiles.

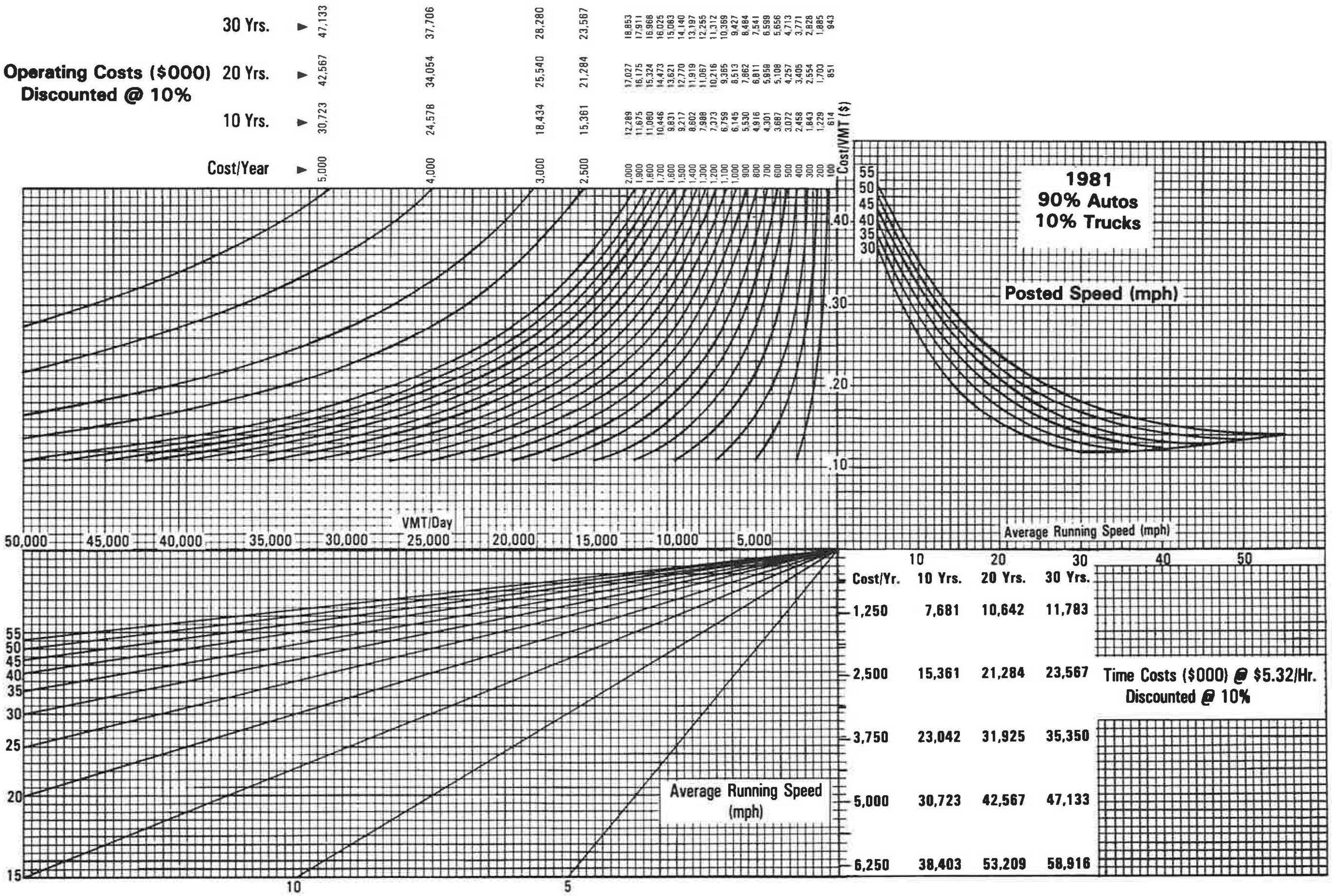


FIGURE 2 Nomograph for 90 percent automobiles, 10 percent trucks.

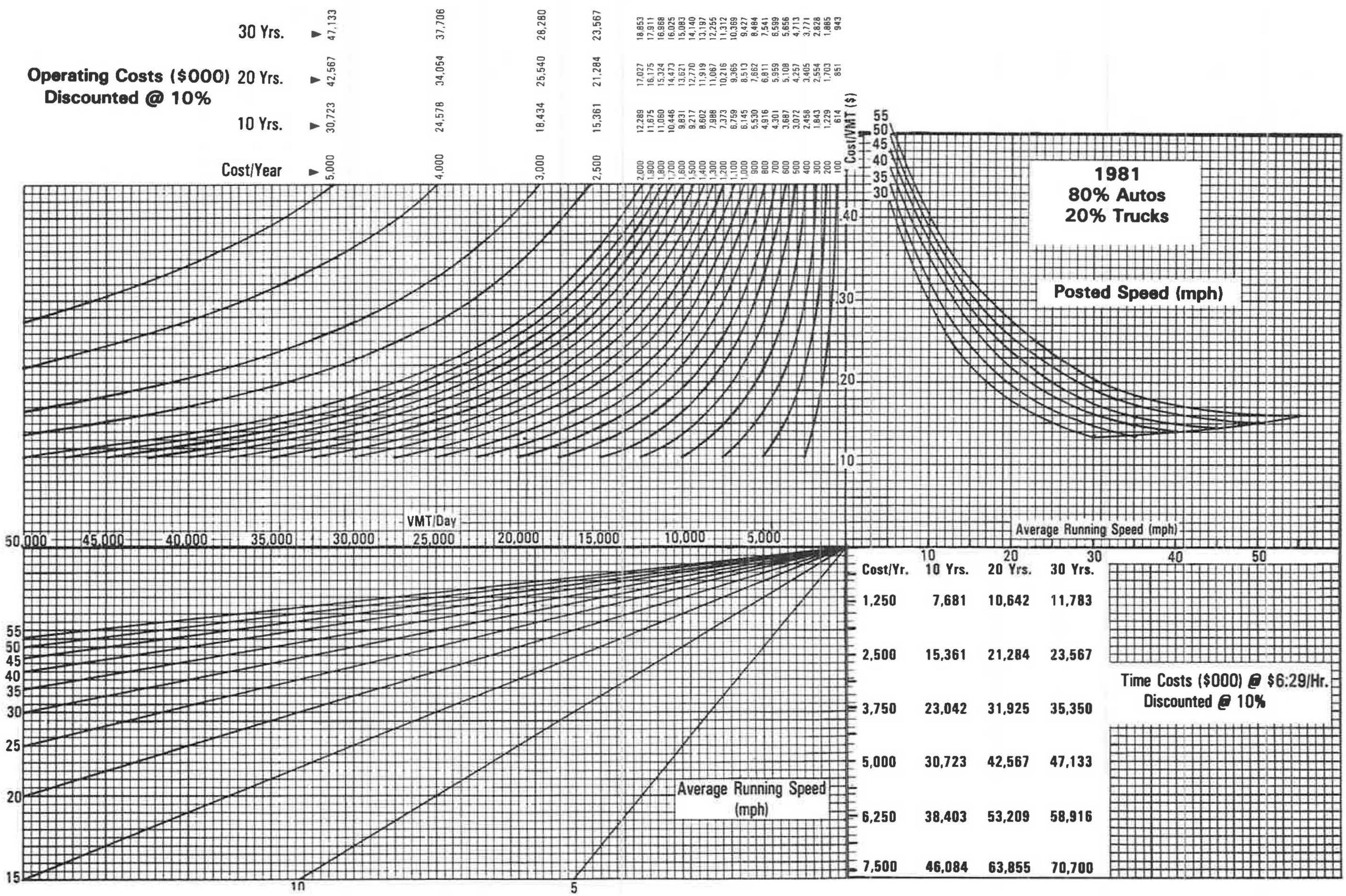


FIGURE 3 Nomograph for 80 percent automobiles, 20 percent trucks.

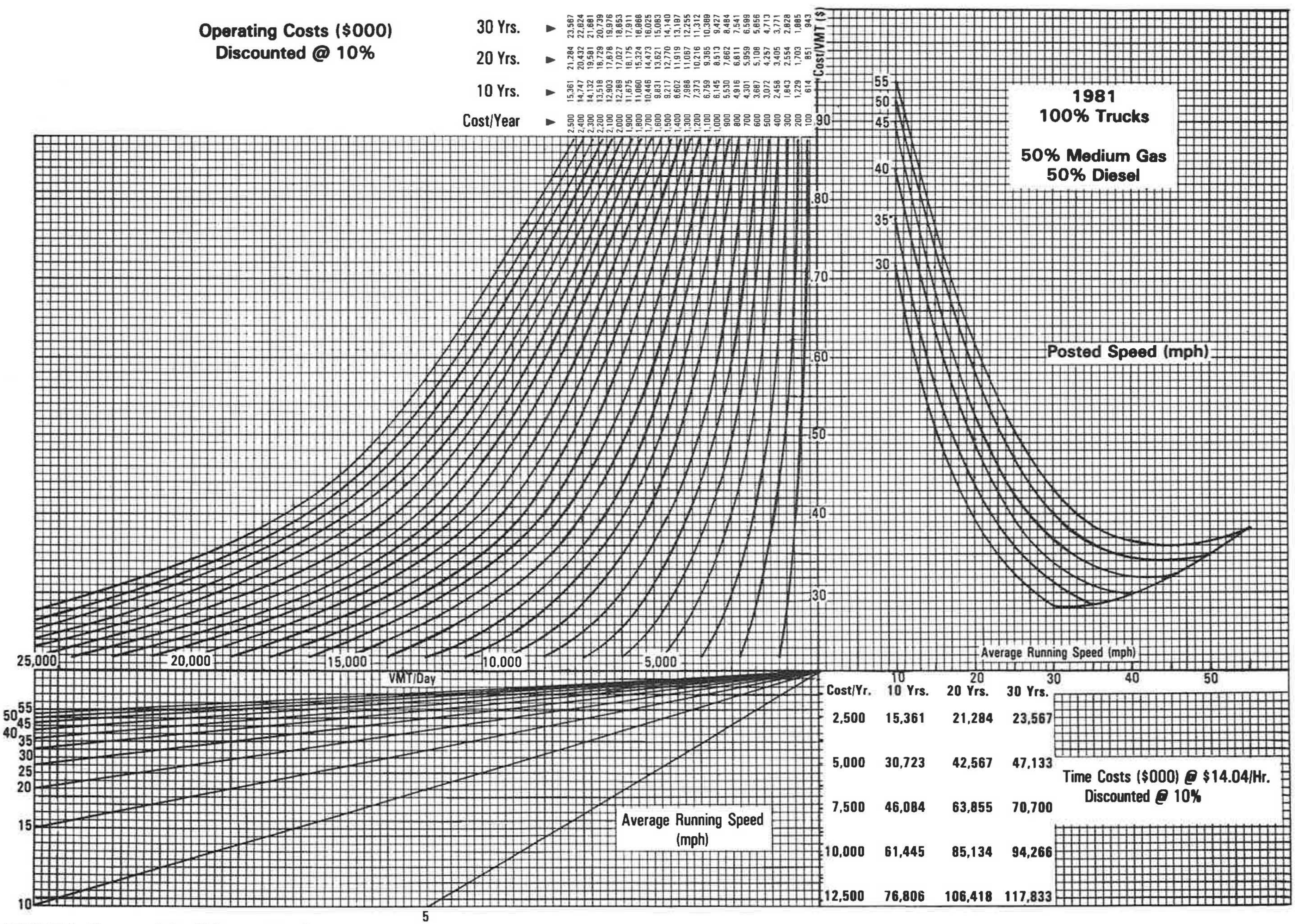


FIGURE 4 Nomograph for 100 percent trucks.

type and congestion, and the quick procedure makes use of an operating cost per vehicle mile traveled (VMT) relationship between those speeds as computed in the simulation models. That cost multiplied by VMT on each section under analysis gives the operating cost for that section for the condition under analysis. Travel time costs have also been developed, and, in conjunction with VMT and average running speed, travel time costs for a section can be computed. For ease of use, traffic is shown as VMT per day. This could be total VMT per day, peak hour VMT per day, and so on. Indeed, peak and off-peak periods might be analyzed separately. All costs shown, however, are annual (365 days). The input costs used in the models were developed separately for both automobile and truck travel. Therefore the automobile and truck operating and travel time costs can be computed separately depending on the percentages of each. For simplicity, or when only generalized approximations of vehicle mix are known, nomographs for a 90-to-10 or 80-to-20 ratio have also been prepared.

Although costs are incurred during implementation, benefits accrue during the life of a project. Maintenance costs are not considered in this procedure. Where they might be thought to vary substantially between the before and after condition, the analyst should procure this information from primary sources. Project costs are generally shown in the PIR in current dollars. Therefore only benefits need be adjusted. To facilitate this operation, both operating and travel time costs have been discounted at 10 percent and shown on the nomographs for estimated project lives of 10, 20, and 30 years. These periods should roughly approximate the life expectancies of most highway projects under consideration.

The quick procedure relies principally on differences in average running speed and congestion that result from highway improvements, with savings resulting from increased efficiency or decreased travel time. It is assumed that most projects will result in improvements in these areas, at least for current levels of traffic. When the improvements themselves, or normal growth patterns, would lead to an increase in traffic, the benefits can be applied to the average increase over the project life, at the same rate as they accrue to the base traffic, as long as such increases do not again create increased congestion and reduce average running speed. Should traffic and congestion be projected to increase beyond that point, the benefits, although less tangible in dollar value, might nevertheless be realized in the increased flow that has been made possible with little or no increased cost per VMT.

The possibility further exists that a highway project might be the cause of new, rather than diverted, traffic. The evaluation of any benefits to be derived from such induced travel, however, is beyond the scope of this quick procedure.

ESTIMATING NEEDED INPUT

The type and scope of many projects lend themselves fairly well to a reasonable estimate of speed and congestion. For simple resurfacing projects, however, it may be difficult to estimate any such changes that might result. Some research has been carried out along these lines in an effort to relate speed to highway condition (3). It was found that at average speeds below 35 mph there is little measurable speed change that can be correlated with surface condition. However, at 35 mph and above, some correlation does appear to exist.

Table 1 can be used as a guide in estimating the magnitude of changes that might be expected as the result of a condition improvement. Surface score refers to the NYSDOT surface condition rating that is scaled from 1 to 10 (4). Assuming one of the initial deteriorated condition scores and a reconditioned average score of 9, the indicated speed change factor might be applied in the absence of any better information.

TABLE 1 Surface-Related Average Running Speeds

Change in Surface Score	Speed Change Factor	Average Running Speed Before Improvement (mph)				
		35	40	45	50	55
3.0 → 9.0	.10	38.50	44.00	49.50	55.00	60.50
4.0 → 9.0	.08	37.80	43.20	48.60	54.00	59.40
5.0 → 9.0[a]	.06	37.10	42.40	47.70	53.00	58.30
6.0 → 9.0	.04	36.40	41.60	46.80	52.00	57.20
7.0 → 9.0	.02	35.70	40.80	45.90	51.00	56.10
8.0 → 9.0	.01	35.35	40.40	45.45	50.50	55.55

[a]Typical repair.

Vehicle mix data also may not be available to the analyst. The proposed project may be site specific--for example, an intersection, in which case the analyst would want to be aware of the prevailing conditions at the location. A 1982 NYSDOT study (5) reported the average values given in the following table. These may be used as a guide in estimating or as default values in cases where the percentage of trucks is not readily available.

Observed Truck Percentages on NYS Highways (percent of AADT)

	Urban	Rural
Interstate	11	26
Non-Interstate	13	16

Another estimated factor is the effect of a highway project on existing traffic on other facilities. It might be desirable to consider such effects with and without the proposed project in place. This is especially true in the case of a bridge or other facility that might be severely restricted or closed altogether.

Finally, as previously mentioned, because accidents tend to be very site specific and therefore difficult to generalize, no attempt has been made to estimate the reduction in accident costs attributable to a proposed project. However, the NYSDOT Traffic and Safety Division has developed a procedure for doing so based on previous accident experience and the type of improvement proposed. Therefore, to evaluate any benefit in reduced accident costs, Traffic and Safety's Safety Benefits Evaluation Form (TE 164) should be used.

USING THE PROCEDURE

Use of the nomographs developed for this quick procedure is quite straightforward: Enter in the upper right quadrant with average running speed and go upward to the intersect with the curve for the posted speed on the section. From that point proceed left to the upper left quadrant to the VMT per day of the section and interpolate between the operating costs curves for 1, 10, 20, or 30 years. Likewise, for that same VMT value, proceed to the lower left quadrant to the line representing the average running speed. At that intersect, proceed right to the vertical travel time cost scale and interpolate for the 1-, 10-, 20-, or 30-year cost. The difference between the sums of the operating and travel time costs for the before and after conditions yields benefits that can be attributed to the project.

The quick benefit-cost procedure affords the analyst a means of estimating the major aspects of a project's worth while the project is still in the preliminary stages. The procedure provides a rationale for the initial priority ranking or the filtering out of projects early in the project development process. The procedure can be applied to a variety of project types, including closed and posted bridges, highway resurfacing, and major reconstruction. Table 2 gives the data needed for applying the procedure in these situations.

As previously mentioned, the procedure is based on average values for the various conditions and current proportions and dollar values in the computation of operating and travel time costs. Update would require recomputation (or possibly a simple factoring) of the nomograph in the upper right quadrant and of the vertical time-cost scale, or, in the simplest case, factoring of the resultant operating and travel time costs to current year. The use of nomographs is intended to keep the procedure simple, quick, and somewhat self-contained. It should also deter one from attributing too much precision to a procedure that uses averages and estimates as basic input.

Since the time this procedure was presented, a version has been programmed for the microcomputer. Input is cued and interactive, and much more flexibility is available in the application of interest rates, project life, and implementation dates. The need to interpolate, inherent in the use of nomographs, has also been eliminated. However, the previously stated caveat must still be kept in mind.

EXAMPLES

Example 1--Resurfacing

It is proposed to resurface a 2-mile section of two-lane highway at a cost of $2 million. The AADT is 5,000 of which 10 percent are trucks. The road is posted at 35 mph but congestion and the condition of the surface keep the average running speed to 20 mph. Resurfacing should increase the average running speed to 25 mph. Are the benefits to be realized from this project in line with the projected costs?

1. Using the nomograph of 90 percent automobiles and 10 percent trucks (Figure 5), start in the upper right quadrant at average running speed = 20 mph and go up to intersect with the curve for posted speed = 35 mph.

2. At that intersection, proceed horizontally to the left to the vertical line at which VMT per day = 10,000 (5,000 AADT x 2 miles).

3. This point is roughly 1/3 of the distance between the curves for $600,000 and $700,000 per year, roughly $633,000. Over the probable 10-year life of a resurfacing project, this can be interpolated as roughly $3,892,000 for operating costs.

4. At the 10,000 VMT per day line, go down vertically to the lower left quadrant to meet the 20 mph line. From the point of intersection, go right horizontally to the vertical time-cost axis and read the value: approximately $950,000 per year = $5,837,000 over 10 years.

5. Sum of before cost = $9,729,000.

6. Repeat steps 1 through 5 for the after situation: Operating costs = $530,000 per year = $3,257,000 over 10 years and time costs = $766,000 per year = $4,707,000 over 10 years. Total after costs = $1,296,000 per year = $7,964,000 over 10 years.

7. Substract total after costs from total before costs over the 10-year period to determine benefits to be accrued = $1,765,000.

8. Compared with the project cost of $2,000,000, the project is not cost-effective, but with a benefit-to-cost ratio of 0.88 it is not too bad.

Example 2--Reconstruction and Widening

For the highway section described in example 1, as an alternative it has been proposed to reconstruct and widen the roadway to four lanes. This would allow traffic to travel at the posted speed (35 mph) as well as provide for future volume increases. This project would cost roughly five times the former and have an assumed life of roughly 20 years. How do projected benefits compare with the cost of such a project?

1. The before costs have already been computed; now that they must be summed over a 20-year period: operating costs = $5,392,000 over 20 years and time costs = $8,088,000 over 20 years. Total before costs = $13,480,000 over 20 years.

2. Using the same 90 percent automobiles and 10 percent trucks nomograph (Figure 5), start again in the upper right quadrant at average running speed =

TABLE 2 Data Needed to Determine Operating and Travel Time Costs

Information Needed	Proposed Project: Reconstruct or Rehabilitate on Same Right-of-Way with or without Widening or Other Capacity Improvements	Repair or Rebuild a Recently Closed Bridge	Repair or Rebuild a Posted Bridge so Posting Can Be Removed: Automobiles	Trucks
Traffic	ADDT and percent trucks	AADT (that did or would use bridge) and percent trucks	AADT for bridge	Detoured traffic
Section length	Section length	Mainline section length from where detour leaves to where it reenters Detour section lengths	Mainline section length affected	Detour section lengths for posted and operating speeds Mainline section length from where detour leaves to where it reenters
Speed	Posted speed before and after Average running speed before and after	Posted speed of mainline after Posted speeds of detour sections	Posted speed of mainline before and after Average running speed of mainline before and after	Posted speeds of detour sections Average running speeds of detour sections

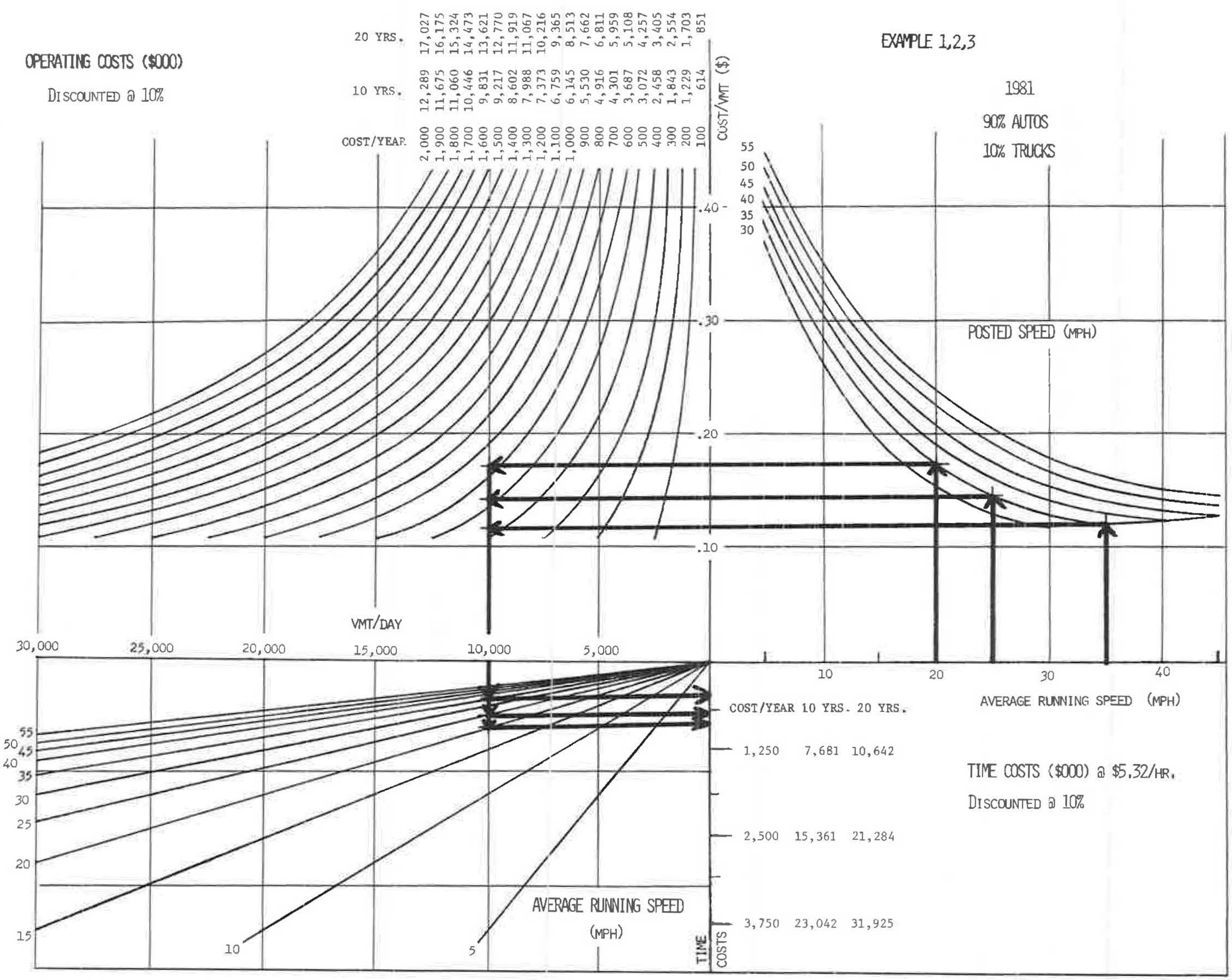


FIGURE 5 Nomograph for examples 1, 2, and 3.

35 mph and go up to intersect with the curve for posted speed = 35 mph.

3. At that intersection, proceed horizontally to the left to the vertical line at which VMT per day = 10,000.

4. This point is roughly 40 percent of the distance between the curves for $400,000 and $500,000 per year, about $440,000. Over the 20-year life of a reconstruction project this can be interpolated as roughly $3,746,000 for operating costs.

5. Again, at the 10,000 VMT per day line, go down vertically to the lower left quadrant to meet the 35 mph line. From the point of intersection, go right horizontally to the vertical time-cost axis and read the value: approximately $500,000 per year = $4,257,000 over 20 years.

6. Sum of after costs = $8,003,000.

7. Subtract total after costs from total before costs over the 20-year period to determine benefits to be accrued = $5,477,000.

8. Compared with the project cost of $10,000,000, benefits over the life of the project would equal about half the project cost.

Example 3--Increased Project Cost

If the project used in example 2 were to cost $15,000,000, at what point would increased traffic justify the higher expenditure?

1. With VMT = 10,000 per day, total benefits = $9,747,000 over the life of the project.

2. Therefore total VMT/$15,000,000 = 10,000 VMT/$5,477,000. Total VMT = 27,388 VMT per day (traffic = 13,694 AADT) to justify the higher cost.

Example 4--Bridge Repair or Reconstruction

A bridge on a 55 mph highway, formerly carrying 5,000 AADT, was found to be structurally deficient and is now posted for 10-ton maximum loads. As a result, 250 trucks per day must now use a detour, posted at 40 mph and operating at 35 mph, which is 4 miles longer than the direct route across the bridge. In addition, the remaining bridge traffic must travel at a 45 mph average for bridge and approaches, a distance of roughly 0.1 mile.

The bridge could be rehabilitated to permit all traffic to use it again at about 45 mph for $2,000,000, or it could be reconstructed to allow all traffic to use it at 55 mph for $4,500,000. From an economic standpoint, what are the relative merits of the null versus rehabilitation versus reconstruction?

Part A--Trucks

1. Detour
   a. Because truck traffic is 250 vehicles per day for 4 miles of detour, the total truck volume of travel is 1,000 VMT per day. Because it is much easier to work at the 10,000 VMT per day scale, it is advisable to do so and then divide the answers by 10.
   b. Using the nomograph for 100 percent trucks (Figure 6), start in the upper right quadrant at average running speed = 35 mph and go up to intersect with the curve for posted speed = 40 mph.
   c. At that intersection, proceed horizontally to the left to the vertical line at which VMT per day = 10,000. This point is roughly 1/4 of the distance between the curves for $1,100,000 and $1,200,000 per year. That is approximately $1,125,000, or divided by 10, $112,500 per year. Over the 20-year life of a good rehabilitation, this can be interpolated as roughly $957,800 for truck operating costs over the detour.
   d. At the 10,000 VMT per day line, go vertically down to the lower left quadrant to meet the 35 mph line. From the point of intersection, go right horizontally to the vertical time-cost axis and read the value. The point falls about 1/6 of the distance between $1,250,00 and $2,500,000 per year. That is approximately $1,458,000 per year, divided by 10, equals $145,800 per year or $1,241,300 over 20 years.
   e. Add truck detour costs of $2,199,100.
2. Rehabilitation or reconstruction
   a. The truck traffic of 250 vehicles per day for 0.1 mile over the rehabilitated bridge amounts to 25 VMT per day. For ease in using the nomograph, especially the time-cost quadrant, this value is 1/40 of the truck VMT over the detour. Thus, it is possible to use the same VMT per day as in the previous calculations and divide the answer by 400 instead of by 10.
   b. Repeat the previous steps for the rehabilitation and reconstruction situations. For rehabilitation: operating costs = $3,300 per year = $28,100 over 20 years, time costs = $2,700 per year = $23,000 over 20 years, and total truck costs under rehabilitation = $6,000 per year = $51,100 over 20 years. For reconstruction: operating costs = $3,500 per year = $29,800 over 20 years, time cost = $2,200 per year = $18,700 over 20 years, and total truck costs under reconstruction = $5,700 per year = $48,500 over 20 years.

Part B--Automobiles

Using the nomograph for 100 percent automobiles (Figure 7) (an approximation because we know that light trucks still use the bridge), start in the upper right quadrant at average running speed = 45 mph (the first two cases), and 55 mph, respectively, and calculate operating and time costs for 475 VMT per day (4,750 automobiles per day for 0.1 mile). Use the 4,750 VMT per day scale and divide answers by 10.

For the before situation: operating costs = $21,300 per year = $181,300 over 20 years, time costs = $16,700 per year = $142,200 over 20 years, and total automobile costs before = $38,000 per year = $323,500 over 20 years. Rehabilitation for automobiles is the same as the before situation. For reconstruction: operating costs = $20,600 per year = $175,400 over 20 years, time costs = $12,500 per year = $106,400 over 20 years, and total automobile costs under reconstruction = $33,100 per year = $281,800 over 20 years.

Part C--Benefits

1. Before: automobile costs = $323,500; truck costs = $2,199,100; and total before costs = $2,522,600.

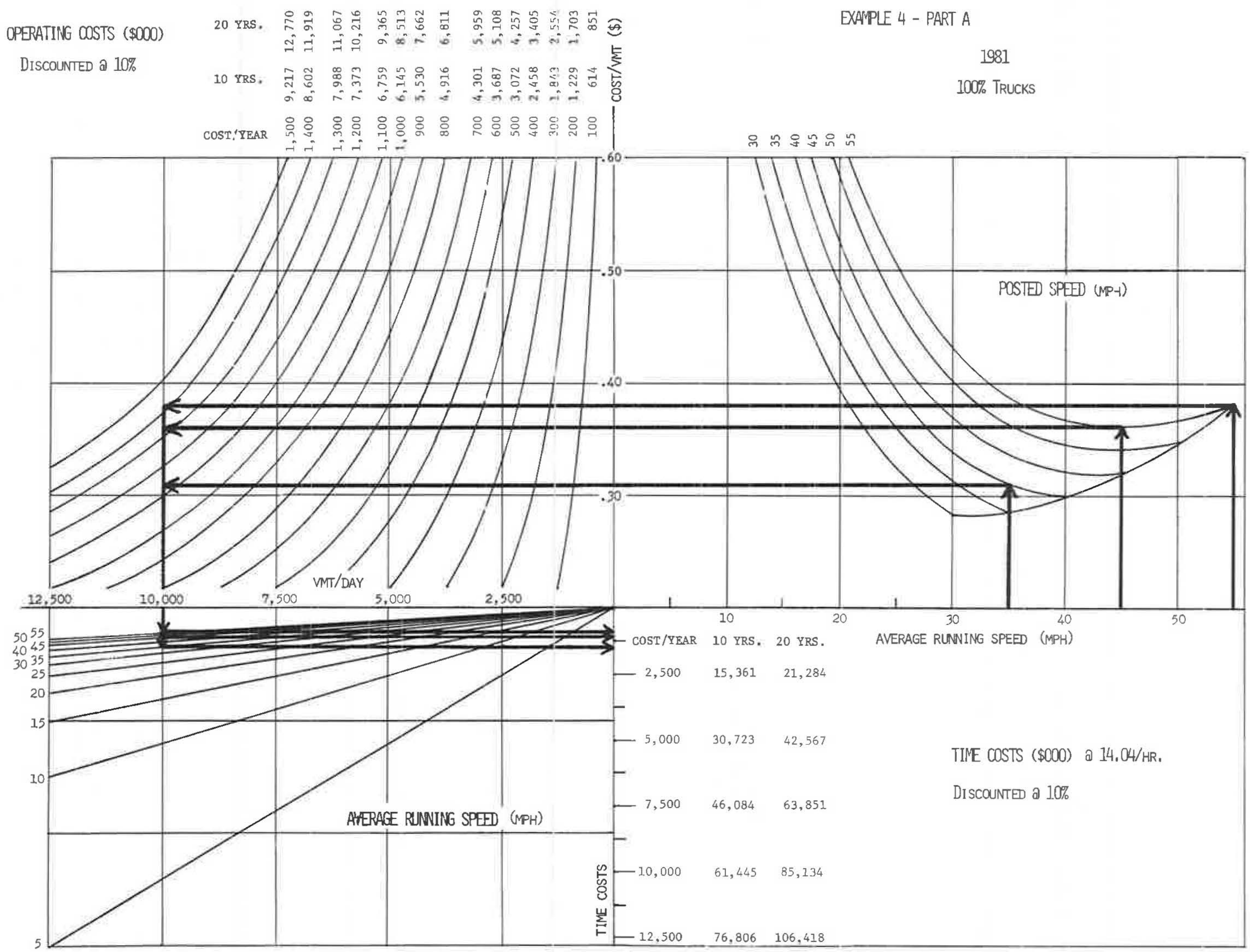


FIGURE 6 Nomograph for example 4, part A.

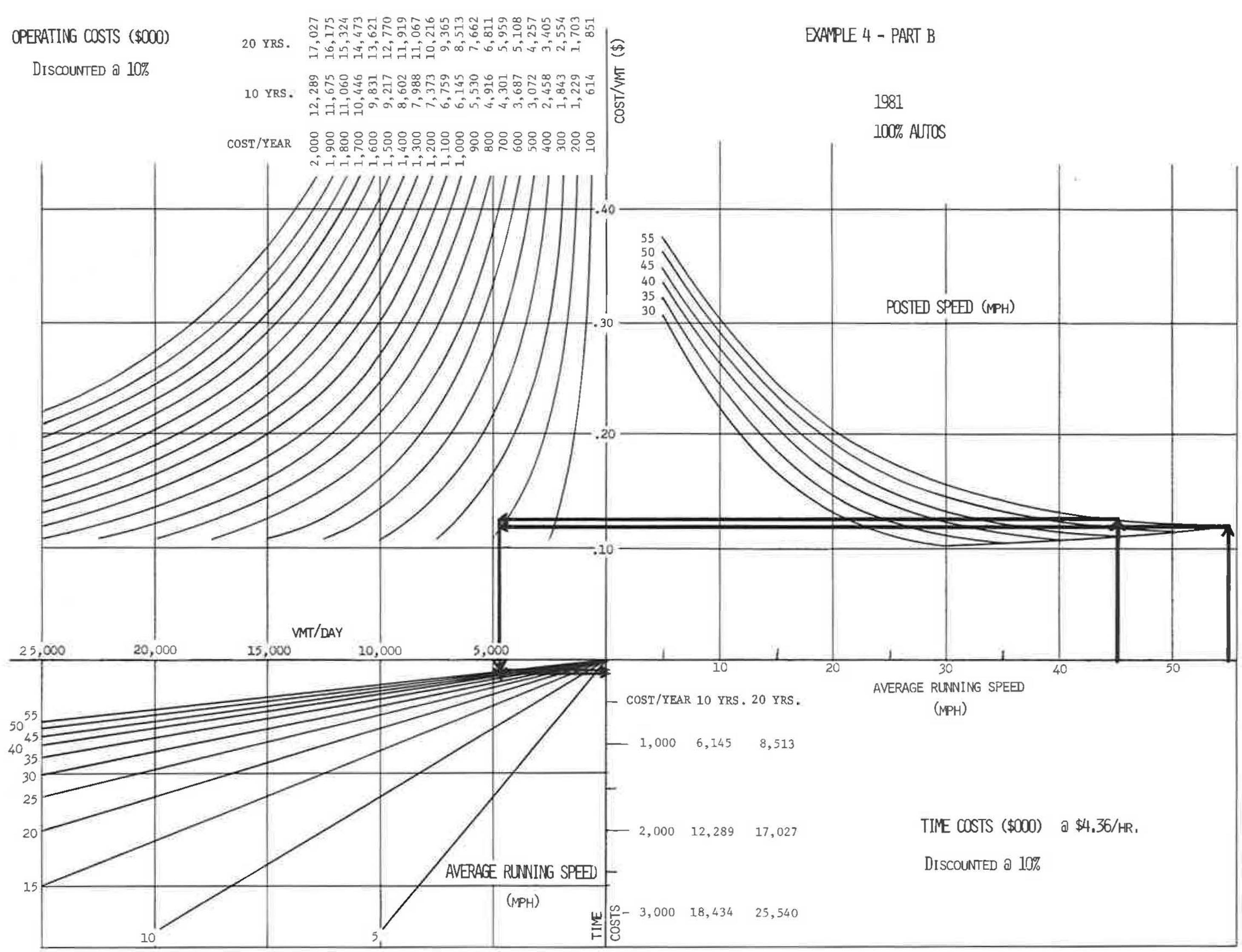


FIGURE 7 Nomograph for example 4, part B.

2. Rehabilitation: automobile costs = $323,500; truck costs = $51,100; and total costs under rehabilitation = $374,600. Benefits over before = $2,148,000 versus rehabilitation project cost = $2,000,000.

3. Reconstruction: automobile costs = $281,800; truck costs = $48,500; and total costs under reconstruction = $330,300. Benefits over before = $2,192,300 versus benefits over rehabilitation = $44,300 versus reconstruction project cost = $4,500,000.

REFERENCES

1. N.R. Schneider. Operating Costs for Passenger Cars on Three Facility Types: Arterials, Junior Expressways, Expressways. Preliminary Research Report No. 10. Planning Division, New York State Department of Transportation, Albany, N.Y., Aug. 1967.
2. P.A. Albin and J.K. Lussi. Documentation of the Highway User Cost Accounting Program. Preliminary Urban Planning Report No. 4. Planning Division, New York State Department of Transportation, Albany, N.Y., Nov. 1971.
3. J.P. Zaniewski, B.C. Butler, G. Cunningham, G.E. Elkins, M.S. Paggi, and R. Machemehl. Vehicle Operating Costs, Fuel Consumption, and Pavement Type and Condition Factors. Federal Highway Administration, U.S. Department of Transportation, Washington, D.C., 1982.
4. D.T. Hartgen, J.J. Shufon, F.T. Parrella, and K.W.P. Koeppel. Visual Scales of Pavement Condition: Development, Validation, and Use. Transportation Analysis Report No. 1. Planning Division, New York State Department of Transportation, Albany, N.Y., March 1982.
5. A. Rapoli and D.C. Fifield. Truck Travel on NYS Highways. Planning Division, New York State Department of Transportation, Albany, N.Y., Oct. 1982.

Publication of this paper sponsored by Committee on Application of Economic Analysis to Transportation Problems.

Transportation and High Technology Economic Development

GRAHAM S. TOFT and HANI S. MAHMASSANI

ABSTRACT

High technology industries constitute a major growth sector of the U.S. economy and have, as such, become the center of considerable attention from state and local economic development agencies and others concerned with national industrial competitiveness. These industries present spatial and production characteristics that differ from those of traditional manufacturing, including special transportation requirements, that have not received adequate attention to date from transportation planners and policy makers. The transportation implications of this major economic change within a framework that considers the stages of the industrial innovation process are discussed in this paper. In particular, implications for air transportation, for both passenger and freight demand, are outlined. Transportation-related measures for fostering high technology growth are addressed, and recommendations are made for further research to address unresolved theoretical and design issues.

There seems to be substantial agreement among economic and sociologic commentators that the United States is on the verge of (and probably already undergoing) an economic and technological transformation that, in the opinion of some, might rival the Industrial Revolution. Its key feature is the rapid movement of the economy away from a traditional heavy industrial base (e.g., steel, automobiles, rubber, textiles) to a knowledge-intensive base (e.g., electronics, telecommunications, biogenetics). The popular media as well as scholarly publications regularly report on the present and future consequences of this industrial realignment on job supply, job type, and job training. To date, however, little has been said about what this means for transportation. If the demand for transportation is largely a derived one, the implications of high technology-oriented economic growth may be significant for various aspects of the transportation sector, including freight movement, both domestic and international; intercity passenger travel; and urban commuting as well as for the trade-offs between transportation and telecommunications.

In this paper possible interrelationships between transportation and high technology economic development are explored, and the principal transportation issues related to this development are highlighted. The intent is to provide an initial framework within which to identify worthwhile areas for future research, and to alert research and practicing engineers, planners, and economic development specialists to potentially important transportation factors in economic development planning for high technology. High technology economic development means the economic activity associated with both research and development (R&D) and manufacturing sectors of advanced technologies. The implications of the adoption of high technology by mature industries or the transportation industry are not treated in this paper.

An important force behind the national concern about high technology issues is alarm at what many observers perceive as the changing stature of the United States in the world economy. The clear U.S. dominance of the global economic order during the 25 years following World War II is now challenged by other advanced nations (e.g., Japan and Germany) that have been able to exploit and build upon U.S. basic knowledge and inventiveness to ultimately produce technologically superior products. One manifestation of this phenomenon is a slippage in competitive edge, especially in manufactured goods, the development, marketing, and production of which are science based and technology driven. A recent report by the Panel on Advanced Technology Competition and the Industrialized Allies of the National Research Council concludes:

> The United States could not have expected to preserve its vast technological leadership. What it must preserve, however, is a strong capacity for technology innovation that is vital to the future growth of the entire American economy (1,p.2).

Efforts at building such a capacity seem to be more advanced, or at least more organized and better articulated, at the state and local levels than at the national level. Driven by an economic recession and interregional shifts in population, many states and localities have recently embarked on industrial development efforts directed at new growth areas of the economy, such as high technology. The early 1980s have witnessed a burgeoning of state study commissions and task forces to address the growth of high technology (2). These reports address such issues as a state's existing advanced technology base, its competitive advantage for high technology, and desirable public initiatives to stimulate high technology growth.

Such efforts, however, have tended to ignore transportation as a potential factor in the formation and growth of high technology industries. This is probably based on the reasonable assumption that advanced technology industries are predominantly labor oriented and amenity oriented. Individuals with the appropriate technical training and drive, operating in an entrepreneurial environment, constitute a key ingredient for the emergence and continued evolution of high technology industries. This new ingredient differs from the traditional factors of concern to basic industries such as proximity to raw materials, energy costs, and transportation costs. However, a more subtle examination may disclose potentially important implications for transportation in maintaining and sustaining technology-oriented economic development. For example, whereas transportation costs might not be highly significant, access to particular modes and level and quality of service might be. This calls for a deeper understanding of the interrelationships between high technology industries and their transportation requirements. A first step in this direction is presented in this paper.

Better understanding requires an adequate characterization of high technology development, which is discussed in the next section. In the third section some of the efforts aimed at high technology growth that have evolved at the state and local levels over the past few years are reviewed. Against this general background the associated transportation issues and implications are addressed in the fourth section. Areas for further research are outlined in the final section of this paper.

CHARACTERIZATION OF HIGH TECHNOLOGY DEVELOPMENT

In this section different perspectives for characterizing the development of high technology industries are examined. The primary interest is in identifying useful perspectives to form the basis of a framework for studying the interrelationships between this kind of economic development and transportation. Three such perspectives are presented: (a) innovation process, (b) industrial organization, and (c) social organization of a local economy.

Various approaches to defining high technology industries have been suggested. For example, some consider R&D expenditures as a percentage of total sales to be the primary indicator, while others rely on the number of scientists and engineers as a percentage of the manufacturing labor force (3). For the purpose of this paper, the definition will be kept broad and purposefully vague. It will thus be sufficient for "high technology" to refer to those advanced products and processes emerging from recent scientific discoveries in microelectronics, electro-optics, biogenetics, and nuclear and materials science. The commercialization of these discoveries is leading to the emergence of new basic industries. Both the R&D and manufacturing sectors of these industries provide tools that will help all sectors of the economy become more productive.

The characterization of high technology development is confounded by a lack of sufficient understanding of the causal relationships between technological innovation and economic development. The role of innovation in the evolution of an economy was addressed in the seminal work of Schumpeter (4) and in subsequent growth theories based on that work. Nevertheless, its role in the current economic environment remains imperfectly understood by economists. In addition, the causal connections between emerging high technology industries and urban development, including spatial ramifications, are equally vague (5). Although the theory is still unclear, observation indicates that high technology growth concentrations have flourished in a relatively small number of urban settings in the United States--the Bay Area's Silicon Valley and MA-128 around Boston are the most notable manifestations of this phenomenon. However, other such concentrations have been developing, and more yet seem to be emerging, reflecting the relative maturity of some older "sci-tech" complexes and the expansion of the knowledge and information base necessary to support such development.

The first of the previously mentioned perspectives for the characterization of these growth phenomena is a rather simplified approach that draws parallels between the industrial innovation process and spatial development activities (6). The industrial innovation process can be disaggregated into three stages: (a) the discovery of new knowledge and invention; (b) the initial product or process development, startup, early production for specialized market segments, and market test; and (c) mass production, universal marketing, and technology diffusion. These will be referred to, respectively, as R&D or invention, adoption and commercialization, and standardization. Note that innovation per se is considered by some to be limited to the adoption and commercialization stage that follows the fundamental scientific discovery stage and includes both the recognition of industrial and market potential and the entrepreneurial activities needed to bring this potential to fruition. Examples of spatial developments or activities corresponding to each of the above three stages are discussed next.

High technology developments of the R&D or invention type are exemplified by the research parks that grow up near leading cooperating technological universities and major research institutions. Developments of the adoption and commercialization type are the spin-off firms and early commercialization activity observed in Silicon Valley, along MA-128, and in Research Triangle Park, North Carolina. These agglomerations include associated service and support firms such as electronic component and plastic molding manufacturers and specialized legal and financial services. Developments of the standardization type include the relocation of somewhat standardized manufacturing plants to low-operating-cost areas, or the location of branch laboratories or plants in promising new high technology concentrations. For example, Advanced Microchip Devices, Inc., headquartered in Silicon Valley, has established branch operations in Austin, Texas. Although simplified, this characterization is helpful in highlighting various transportation implications discussed in the fourth section of this paper.

A second perspective from which to characterize high technology development with transportation in mind is industrial organization. At least two component phenomena can be identified in the structure and composition of high technology industries:

1. The Agglomeration Phenomenon: Most high technology industries are composed of a large number of small firms. They are highly specialized and therefore depend on other firms for supplies, basic services, finance, and marketing. They also depend on spatial proximity to each other for networking, "stealing" of ideas, hiring of specialists, and subjective risk reduction.
2. Spatial Diffusion of Firm Functions: Because of improved communications and airline travel high technology firms show some propensity for locating different firm functions in regions with different comparative advantages. An example of such a multilocational firm is Star Technologies, Inc., a computer component manufacturer, which has its corporate headquarters in Portland, Oregon, its R&D facilities in Minneapolis, Minnesota, and its production facilities in Sterling, Virginia.

A third perspective from which to characterize high technology development is the social organization of a local economy. Technological innovation does not concern only hardware. Such innovation must also be understood in terms of the interplay of products, processes, and related human behavior. The social component of technological innovation includes various institutional arrangements, including those between public and private bodies, that allow for the timely flow of resources and for the management of uncertainties. Some local institutional arrangements that are considered important are access to venture and seed capital, specialty legal and accounting services, and a climate of mutual support between technology firms and nearby research establishments. This perspective may have implications for transportation. The structure, power, and composition of local transportation agencies and their funding arrangements may enhance or inhibit local technological innovations and technology firm formation.

TYPOLOGIES OF PUBLIC INITIATIVES

Key features of programs and strategies that have evolved at the state and local levels are reviewed in this section. Policy options at the state level are first identified; then examples of strategies developed at the city level are given. Third, examples of a few transportation-specific initiatives that have been proposed or implemented are discussed.

State Strategies

As the U.S. economy slowed down during the 1970s, state governments stepped up their efforts to retain or capture their share of a shrinking "economic pie." Initial strategies such as business incentives, especially through tax competition and industry assistance, have become so competitive that their desired effects on firm location decisions may have been neutralized (7). More recently focus has shifted to targeting state industrial development and new firm formation in growth areas of the economy, especially high technology. The early 1980s have witnessed a plethora of state study commissions and task forces dealing with high technology industry growth. A recent Office of Technology Assessment (OTA) census (2) identified nine existing task forces. In a number of states, task forces have been disbanded leaving in their wake nonprofit, semiprivate foundations or corporations to administer and provide funding for recommended high technology development.

State initiatives can be characterized in at least two ways: by overall strategies and by types of policy instruments. The OTA census suggests that states appear to be capitalizing on their strengths by focusing on those stages of the industrial innovation process that already give them a comparative advantage. States, such as Illinois and Michigan, with well-developed networks of R&D institutes and technological universities are giving particular attention to the resources of these systems. States that are known for their innovative and entrepreneurial environment, including capacities for new product marketing and venture capital, are concentrating on new product and process development, for example, California, Connecticut, Massachusetts, and Hawaii. States that are known for mass production are concentrating on the attraction of spin-out branch plants or on the modernization of their existing industries using advanced technologies, for example, Alabama, Arkansas, and Mississippi.

The second approach to characterizing state high technology initiatives is that employed in a recent National Governors' Association report (8). Here the various policy instruments available to a state have been categorized as follows:

1. Policy Development Units: task forces, commissions, economic development agencies, public-private partnership committees.
2. Economic Incentives: tax and business incentives, loans and loan guarantees, set asides, venture capital funds.
3. Technical Support for Business: technology transfer programs, incubator programs, engineering extension.
4. Worker Training and Involvement Programs: vocational and technical college offerings, customized job training, worker participation, and job enrichment.
5. Industry-University Linkages: joint ventures for R&D, innovation centers.

In both reports cited, a discussion of transportation issues is conspicuous in its absence. Physical site determinants in general receive little coverage. The reasons for this could be (a) that transportation is an unimportant determinant in high technology firm location or formation, (b) that state transportation strategies and policies are not addressed specifically under high technology initiatives but more broadly under economic development initiatives in general, or (c) that transportation is important but overshadowed by other growth determinants such as supply of skilled labor and venture capital.

Some hard evidence indicates that transportation is not unimportant in location decisions. A nationwide survey of high technology firms by Robert Premus of the Joint Economic Committee (JEC) shows transportation ranked sixth as a factor in interregional location decisions and ranked fifth and ninth in intraregional location decisions (see Tables 1 and 2) (9). Respondents were asked to rank each of the attributes given in these tables as "very significant," "significant," "somewhat significant," or "no significance" with respect to their location choices. The percentages of very significant and significant responses were added to obtain an index of overall importance. For interregional location decisions, although transportation ranked lower than labor, tax, academic, and cost of living considerations, it was considered more important than regulations, energy, cultural amenities, climate, and raw materials. For intraregional location decisions "good transportation for people" scored high. The JEC report concludes: "Clearly traditional locational factors of access to markets and raw materials were not important factors for high technology plant location decisions. Transportation entered the decision matrix in another manner, however. A good transportation system for people was rated significant or very significant by 76.1 percent of the respondents. This finding is consistent with the view that commuting time is becoming an important factor influencing the migration decision of engineers, scientists, professionals and technicians required by high technology companies" (9,p.28).

TABLE 1 Factors that Influence the Regional Location Choices of High Technology Companies *(9)*

Rank	Attribute	Percentage Significant or Very Significant
1	Labor skills and availability	89.3
2	Labor costs	72.2
3	Tax climate within the region	67.2
4	Academic institutions	58.7
5	Cost of living	58.5
6	Transportation	58.4
7	Access to markets	58.1
8	Regional regulatory practices	49.0
9	Energy costs and availability	41.4
10	Cultural amenities	36.8
11	Climate	35.8
12	Access to raw materials	27.6

TABLE 2 Factors that Influence the Location Choices of High Technology Companies Within Regions *(9)*

Rank	Attribute	Percentage Significant or Very Significant
1	Availability of workers	96.1
	Skilled	88.1
	Unskilled	52.4
	Technical	96.1
	Professional	87.3
2	State and local government tax structure	85.5
3	Community attitudes toward business	81.9
4	Cost of property and construction	78.8
5	Good transportation for people	76.1
6	Ample area for expansion	75.4
7	Proximity to good schools	70.8
8	Proximity to recreational and cultural opportunities	61.1
9	Good transportation facilities for materials and products	56.9
10	Proximity to customers	46.8
11	Availability of energy supplies	45.6
12	Proximity to raw materials and component supplies	35.7
13	Water supply	35.3
14	Adequate waste treatment facilities	26.4

City Strategies

Localities have been becoming more aggressive in their efforts to retain, expand, and attract industrial development. Some cities, such as Philadelphia and San Francisco, have embarked on broad-based strategic planning processes of which the industrial sector is only a part. Other cities are concentrating their strategic planning on the manufacturing sector and high technology in particular, for example, San Antonio and Indianapolis.

In "San Antonio's Place in the Technology Economy" (10) the city sets forth its review of opportunities in high technology and a blueprint for action. Its shopping list of general support actions needed includes research parks, educational investments, venture capital, attracting R&D funds, foreign technology investments, statewide technology policies, technology exports development, and marketing a technology image. Although the report pays attention to San Antonio's geographical and cultural ties with markets in Latin America, transportation initiatives are hardly mentioned.

In "A Strategic Plan for the Industrial Development of Indianapolis" (11) a priority list of targeted high technology industries is selected through a screening process of economic analyses. This primary tier of potential achievers includes industrial automation, telecommunications, instrumentation, and health care technology. A complementary list of secondary tier industries including several of Indianapolis' historical achievers is targeted to provide a cradle for the younger, primary tier industries. Included in this secondary tier are wholesale trade, trucking, and air transportation, all of which depend heavily on Indianapolis' geographical location and transportation networks. However, apart from passing mention of the deteriorating transporting infrastructure and the possible need for airport expansion, the connection between transportation strategies and investments in the second tier and industrial growth in the primary tier is not made.

Examples of Transportation-Specific Initiatives

In at least two states transportation-specific initiatives for high technology development have been articulated.

Tennessee

In Tennessee the Governors' Task Force made a thorough analysis of a survey, conducted by the U.S. Department of Commerce, of eight university-related research and technology parks. Nine elements were concluded to be common to all such successful ventures, including easy access to Interstate and national commercial air transportation systems (12).

Tennessee's technology corridor concept for the Knoxville-Oak Ridge areas give particular attention to high-speed arterial highways and commercial air services, as well as adequate cheap land and the campuslike, semirural environment along the arterials. Tennessee's plan is probably the leading example of a state-formulated technology growth strategy built around an existing configuration of university and research establishments combined with an existing and proposed configuration of transportation facilities.

Massachusetts

In Boston, a major high technology industrial park is to be located adjacent to Logan International Airport. The park will provide companies with space for research and development, manufacturing, warehousing, and distribution of products. Easy access to air cargo and general aviation facilities is expected to reduce ground handling costs as well as loss and damage. Another feature of that complex will be its future designation as a foreign trade zone (FTZ).

A foreign or "free" trade zone is a site within the United States cordoned off from U.S. Customs Service regulations. It allows a company to import goods duty free provided the finished product is ulti- mately exported. If sold domestically, duties are imposed only on the finished goods. Although FTZs can be located anywhere, locations close to inter- national airports are frequently preferred because they reduce surface transportation costs.

TRANSPORTATION IMPLICATIONS

It is evident from the preceding discussion that transportation has been largely neglected in state and local planning efforts directed at high technology development. Unlike traditional heavy manufacturing, proximity to raw materials and markets, as a transport cost minimization objective, is not of prime concern to high technology firms. Transportation has not been considered a key determinant of the location of these firms; this has earned them the label "footloose" industries.

Communication and exchange of information and close proximity to young markets are of the essence in the development of high technology activities. The special features of these firms and the activities that they engage in have important spatial requirements, which should not be overlooked in current planning efforts and programs to facilitate and support technological innovation through transportation initiatives. This section examines, qualitatively, the nature of these requirements and the resulting opportunities that may arise to positively influence the economic development process. The characterization presented in the second section will serve as the basis of a framework for examining the transportation interrelationships with the various stages of the industrial innovation process.

The discovery or R&D or invention stage is people and idea dependent in addition to requiring scientific resources. These scientific contact systems (13) involve highly trained scientists and engineers working intensively on difficult frontier topics. Some of the associated transportation-generating requirements are frequent meetings between scientists and attendance at scientific workshops, conferences, and symposia. These entail intercity travel because only a handful of experts in many of the fields of interest may be located in any one place. Air service is the appropriate mode for such travel because of the high value of the time of these professionals. Therefore even at the R&D stage where the benefits of spatial concentration are readily apparent (sources of inspiration, ideas, leads to problem solutions, and rapid dissemination of partial results obtained by colleagues and competitors), a potentially significant transportation component can be identified.

Furthermore the types of individuals involved in these activities generally place a high premium on overall urban quality of life (14). Accessibility of work and recreation opportunities has long been recognized as an important component of an urban area's livability and desirability. In particular, congestion levels accompanying the home-to-work commute usually play a significant role in an individual's residential location opportunities and choices and thereby contribute to overall satisfaction with life-style. Of course these factors are not restricted to the R&D stage; they are present in the other stages as well.

In the second stage, adoption and commercialization, dependence on contact systems is even greater. In this stage, the scientific aspects need to be combined with entrepreneurial skills to secure appropriate financial and human resources for launching test products and processes and to convincingly establish the commercial viability of a scientific discovery. Thus a special class of extensive and intricate business contact systems operates in conjunction with the scientific contact systems. For example, a venture capitalist working within a 200-mile-radius service area may visit a client firm two to four times a month in the early stages.

From a locational standpoint the adoption and commercialization stage is facilitated by a location amid concentrations of firms engaged in similar lines of activity; these are likely to be clients of and suppliers to the newly emerging firm. The latter may itself be a spin-off venture of an existing larger firm. Initial start-up costs, primarily those of essential knowledge, are likely to be reduced by proximity to such a concentration, and there is the possibility of "raiding" other firms for key professionals. In that regard, agglomeration economies (of an informational nature) seem to play a key role in the location of technologically advanced industries at this stage of their development. Jon Levine describes Los Altos Hills, an established suburb of Silicon Valley, as a place "where deals are cut in barbershops and entrepreneurs are made on tennis courts" (15).

The apparent low importance of transportation costs as a locational determinant for high technology industries in the adoption and commercialization stage may be deceiving. William Lathan points out that agglomeration economies can be viewed as a special case of transportation cost minimization (16). This suggests several transportation attributes conducive to those activities. First, the need for frequent air travel identified in connection with the earlier R&D stage is still present and actually increases substantially because of associated entrepreneurial activities. Time sensitivity in this highly volatile and rapidly changing arena is great for many face-to-face contacts between key actors, further pointing to the criticality of high-quality air service (i.e., frequent direct connections to and from major high technology concentration areas).

In addition, the adoption and commercialization stage involves the initiation of manufacturing activities, requiring the transport of material inputs to the plant and outputs to clients who are often other high technology manufacturers. Shipments are typically highly valued, time sensitive, and of relatively low bulkiness; they often require careful handling. These attributes are usually considered indicative of a high likelihood of using air freight--an assertion that can be supported by an examination of the general characteristics of air shipments (17,18). The air freight requirements of high technology development are further discussed later in this section.

The availability of affordable middle-class housing and automobile journey to work are other important considerations for firms in the adoption and commercialization stage. The heavy concentration of professional and white-collar workers in the high technology work force is illustrated by the following aggregate figures of the Massachusetts High Tech Council, many members of which are located in the MA-128 concentration (18).

Type of Worker	Percentage
Professionals	34.7
Technical paraprofessionals	13.1
Administrative and clerical	21.5
Skilled labor	24.3
Production	6.3

In the standardization stage increasing geographic separation of manufacturing from corporate control, R&D, and other functions can be observed (19, Introduction). Although the process by which high technology corporations make decisions regarding organizational structure and the corresponding spatial allocation of activities is not well understood, factors such as land and skilled labor availability (and cost), quality of life, and tax and business climate seem to play an important role in the location of branch manufacturing plants (9). Multilocational firms generate demand for frequent travel (among the various branch locations), which typically requires air service, in addition to the previously mentioned travel needs of scientific and technological personnel. Furthermore, the air mode is often an essential element of these firms' logistic strategies and is relied on for the transport of incoming and outgoing freight on a regular, planned basis as well as for meeting emergency-type requirements.

It can thus be seen that, in all three stages of the industrial innovation process, a significant role exists for air transportation of both passengers and freight. In addition to special air transport needs, there is the high-tech highways phenomenon (20). Outer rings or access arterials appear to provide tolerable congestion levels essential to achieving the desired overall quality of life that is of prime concern to the highly trained scientists and professionals on whom high technology industries thrive. They also provide access to affordable semirural, campuslike industrial land and proximity to suburbs and exurbs. More subtly, high-tech highways provide a desirably aesthetic setting for high technology firms seeking highly visible locations. It appears that, for many high technology firms, buildings and grounds have "monument value." Freeway routes create such sites.

Therefore, although it is not a primary locational determinant, transportation can greatly enhance and support high technology activities. It also has the potential of acting as a catalyst to accelerate the formation of high technology concentrations, particularly when transportation-related measures are coupled with other features such as tax incentives, research and industrial park developments in the vicinity of airports and interchanges, and the like. In other words, although transportation is not a sufficient factor, it is clearly a necessary factor that ought to be considered in medium- to longer-term planning and investment strategies at the local, state, and national levels.

Special Considerations for Medium-Sized Urban Areas

Increasingly, medium-sized urban areas such as Austin, Texas; Raleigh, North Carolina; and Albuquerque, New Mexico, are witnessing the emergence and growth of high technology activities. An overall high quality of life (e.g., housing opportunities, proximity to outdoor activities), the presence of major technological universities, a favorable tax and labor climate, and other factors combine to enhance the attractiveness of many of these areas to high technology firms. This phenomenon has important transportation implications for these areas, given the special requirements of high technology industries discussed throughout this section. The special considerations applicable to medium-sized urban areas resulting from high technology development are discussed elsewhere (21). In the long run air service and aviation facilities may not be adequate in many of these smaller urban areas. In addition, the restructuring of the nation's trunk airline networks following the 1979 deregulation has resulted in an overall loss of direct service to and from many small and medium-sized urban areas (21,22).

Further, when considering zoning for research and technology parks in technology growth communities, transportation and land use planners would do well to apprize the development potential created by existing beltways and access arterials. The location of research parks in low visibility areas, such as the Purdue Research Park in West Lafayette, Indiana, may prove to be a dubious, slow-growth proposition.

High Technology and International Transportation

In addition to the previously discussed domestic transportation implications of high technology development, the international dimension ought to be considered. Because these industries are labor intensive and most countries have some concentration of technological expertise, a number of observers argue that worldwide economic integration is likely to occur at an early stage and include the less developed countries (23,24). For example, before Japan began making microprocessing chips for its hand-held electronic calculators, the chips came from the United States, the steel housing came from India, and the final product was assembled in Singapore or Indonesia.

The globalization of production and manufacturing calls for appropriate world freight system development and trade policies guaranteeing the prerequisite degree of freedom. Because of the nature of the shipments, international air cargo can be important to these industries. Thus the concept of FTZs is receiving increasing attention in the United States, especially in the vicinity of international airports (25).

FTZs in the vicinity of airports constitute one example of the array of innovative transportation-related measures and policies that could be initiated at the local and state levels to foster economic renaissance through high technology development. Further attention to the transportation and spatial aspects of high technology industrial development is warranted and is bound to yield greater understanding of the phenomena at hand and to lead to identification of related options and strategies with potentially significant long-term effects. Additional thoughts on this matter and recommendations for further research are given in the next section.

CONCLUSION

While alarm and studies concerning U.S. competitive edge and trade position in advanced technology proceed at the national level, policy specifics and strategic action advance at the state and local levels. Bruce Nussbaum describes the mounting interstate and interregional competition over high technology as a "nascent second 'war between the states'" (26,p.14). By and large to date these initiatives have not made connections between transportation and the advancement of high technology growth. This is partly because of a dearth of hard data on the subject and the recondite nature of the connections.

By means of an elementary characterization of high technology industrial development, a case for the importance of transportation in at least four areas has been developed. The areas are (a) the journey to work of the predominately professional, white-collar work force; (b) business air travel for scientific, technical, and business purposes; (c) high air freight volume due to the high value, low bulk, time-sensitive, and fragile nature of shipments; and (d) clean, campuslike, semirural, highly visible sites in the vicinity of major arterials, Interstates, and airports.

Recent examples from the Tennessee Technology Corridor and the Logan International Airport Technology Park Development indicate that transportation investments and strategies may play a significant role in high technology growth initiatives. Further research is needed in three areas: description of phenomena, theory building, and planning and design tools.

An improved characterization of high technology industries, disaggregated to the four-digit standard industrial classification level, is needed. A better handle on the commodity flows in and out of high technology industries and the travel patterns of their workers is also needed.

A strong theoretical base would be enhanced by a fuller understanding of the agglomeration phenomenon. More knowledge about the dynamics of firm emergence and clustering is needed as is a better understanding of the apparent footlooseness of high technology firms. Even though high technology firms may be little concerned about the transportation costs of inputs and outputs, their transportation needs in terms of quality of service and mobility of personnel appear to be important.

From the planning and design perspective, the land and building space needs of high technology firms are not well documented. State and local government transportation options for encouraging high technology research or manufacturing development have not been articulated. Although research on this topic is not yet sufficiently advanced to provide analytical methodologies or policy frameworks for transportation planners and engineers, two guiding principles can be deduced. First, the quality of transportation services appears to be important, and transportation costs may not be. Second, proximity to transportation facilities, such as an airport or interchange, appears to enhance growth either directly when coupled with other policy initiatives such as a foreign trade zone or indirectly by providing affordable, spacious industrial sites. Finally, a mathematical model for forecasting long-term transportation investments associated with high technology industries may be useful.

The National Research Council's Panel on Advanced Technology Competition calls for the strengthening of the national capacity for technological innovation. Some elements that already support U.S. innovation capability are a strong research infrastructure, technically educated manpower, a technically literate population, tax and business incentives, and technology transfer programs. The challenge for transportation engineers and planners is to examine the adequacy and appropriateness of transportation facilities and services as an additional element in the overall scheme of rapid technological and economic adjustment expected as the United States moves into an age of knowledge-based economy.

ACKNOWLEDGMENTS

Partial support for the research that led to this paper was provided by U.S. Department of Transportation contract No. DOT-RC-92004 to Purdue University's Automotive Transportation Center and a subcontract to the Center for Studies in Statistical Mechanics at the University of Texas at Austin. Additional partial support was provided by a grant to H. Mahmassani from the Bureau of Engineering Research of the University of Texas at Austin. The authors have profitted from discussions with many collaborators and students, particularly Robert Herman (University of Texas at Austin), Kumares Sinha (Purdue), and Robert Ayres (Carnegie-Mellon). The authors remain solely responsible for the contents of this paper.

REFERENCES

1. International Competition in Advanced Technology: Decisions for America. Panel on Advanced Technology Competition and the Industrialized Allies, National Research Council, Washington, D.C., 1983.
2. Technology, Innovation and Regional Economic Development. Office of Technology Assessment, Congress of the United States, Washington, D.C., May 1983.
3. S.J. Graham. The Determinants of the Geographical Distribution of the Formation of New and Small Technology-Based Firms. Ph.D. dissertation. Michigan State University, East Lansing, 1981.
4. J.A. Schumpeter. Business Cycles: A Theoretical, Historical and Statistical Analysis of the Capitalist Process. 2 vols. McGraw-Hill, New York, 1939.
5. E.J. Malecki. Industrial Geography: Introduction to the Special Issue. Environment and Planning A, Vol. 14, 1982.
6. M.D. Thomas. Industry Perspectives on Growth and Change in the Manufacturing Sector. In Industrial Location and Regional Systems: Spatial Organization in the Economic Sector, edited by Rees, Hewings, and Stafford. Bergin & Garvey, Hadley, Mass., 1981.
7. Regional Growth: Interstate Tax Competition. Advisory Commission on Intergovernmental Relations, U.S. Office of Management and Budget, Washington, D.C., 1981.
8. State Initiatives in Technological Innovation. Preliminary rept. Task Force on Technological Innovation, National Governor's Association, Washington, D.C., Feb. 1983.
9. Location of High Technology Firms and Regional Economic Development. Joint Economic Committee, Congress of the United States, Washington, D.C., 1982.
10. H.G. Cisneros. San Antonio's Place in the Technology Economy. Office of the Mayor, San Antonio, 1982.

11. A Strategic Plan for the Industrial Development of Indianapolis: Economic Analysis and Strategies. Central Research Systems, Indianapolis, Ind., 1982.
12. Technology Corridor. Governor's Task Force, Office of the Governor, Nashville, Tenn., 1982.
13. B. Thorngren. How Do Contact Systems Affect Regional Development? Environment and Planning, Vol. 2, 1979.
14. J.M. Pennings. The Urban Quality of Life and Entrepreneurship. Academy of Management Journal, Vol. 25, No. 1, 1982.
15. J. Levine. Living the Dream. Venture, March 1983.
16. W.R. Latham. Locational Behavior in Manufacturing Industries. Martinus Nijhoff, The Netherlands, 1976.
17. R.A. Ausrotas and N. Taneja, eds. Air Freight: The Problems of Airport Restrictions. FTL rept. R79-1. Flight Transportation Laboratory, Massachusetts Institute of Technology, Boston, 1979.
18. P.S. Smith. Air Freight: Operations, Marketing and Economics. Faber and Faber, London, England, 1974.
19. J. Rees, G. Hawings, and H. Stafford, eds. Industrial Location and Regional Systems: Spatial Organization in the Economic Sector. Bergin, New York, 1981.
20. K. Farrell. High-Tech Highways. Venture, Sept. 1983.
21. H. Mahmassani and G. Toft. Transportation Issues Related to High Technology Development in Medium-Sized Urban Areas. Submitted for publication.
22. Y. Chan. Airline Deregulation and Service to Small Communities. In Transportation Research Record 851, TRB, National Research Council, Washington, D.C., 1982, pp. 29-37.
23. F.E.J. Hamilton. Industrial Systems: A Dynamic Force Behind International Trade. Professional Geographer, Vol. 33, 1981.
24. I. Wallerstein. The Capitalist World Economy. Cambridge University Press, Cambridge, England, 1979.
25. J.V. Barks. Import-Beset Metals Firms Send Out SOS on FTZ's. Iron Age, June 23, 1980.
26. B. Nussbaum. The World After Oil. Simon and Schuster, New York, 1983.

Publication of this paper sponsored by Committee on Economic Development of Land and Transportation Systems.

Comparative Economic Analysis of Asphalt and Concrete Pavements

RALPH D. SANDLER, EDWARD T. DENHAM, and JACK TRICKEY

ABSTRACT

A comparative economic analysis of alternative asphalt and concrete pavement design is presented in this paper. Both a life-cycle cost comparison and an economic impact analysis were conducted. In this study, using specific designs for a hypothetical rural Florida project and 1983 Florida estimated costs, the asphalt pavement design was the clear and unambiguous economic choice at 5, 7, and 10 percent discount rates and for both 30- and 40-year project lives. A sensitivity analysis of energy price impacts was conducted by assigning asphalt material prices a 2.6 percent differential inflation rate. The asphalt pavement design was again the economic choice in all comparisons. A comparative life-cycle cost analysis should be conducted routinely. It has great potential for resolving ambiguous public debate as well as maximizing the economic efficiency of public expenditures. An economic impact analysis, which consisted of an assessment of the earnings and employment effects of each design, was accomplished by applying an input-output model, RIMS II, to industry-specific input costs. The study found an employment benefit in the use of concrete; however, the interpretation of this advantage must be left to the decision maker. Further research is recommended.

The literature consistently recommends the use of life-cycle cost analysis in evaluating alternative pavement designs; however, there are few articles that discuss the application of this technique to a practical case study. Practical examples can be very useful for exploring how sensitive the outcome of an analysis is to different and often controversial parameter assumptions such as the discount rate, the treatment of inflation, and the economic life of a project.

In 1983 the Florida Department of Transportation (FDOT) completed a study, A Comparative Analysis of Asphalt and Cement Concrete (1), on the relative merits of the use of these two products for highway construction. The portion of that study concerned with conducting a life-cycle cost analysis is discussed in this paper. The following issues are specifically addressed.

1. Is the initially higher construction cost of cement concrete pavements mitigated by reduced future maintenance costs and longer facility life?
2. Will the future price of asphalt, as a scarce natural resource, further erode the initial cost advantage of asphalt pavement?

The employment impact of a public investment decision is often considered more important by policy makers than minimizing the cost of an investment, especially during periods of economic contraction. Despite the apparent interest of elected officials in the economic impact of a project, the issue has seldom been the subject of empirical research. For this reason the FDOT study was broadened to include an assessment of the earnings and employment effects of each pavement design using Florida-specific multipliers from the Regional Input-Output Modeling System (RIMS II) developed by the U.S. Bureau of Economic Analysis.

The focus of this paper is on the analytic approach rather than the results of this Florida-specific case. Although other designs in other regions may produce different outcomes, the same principles and techniques of economic analysis should still be applicable.

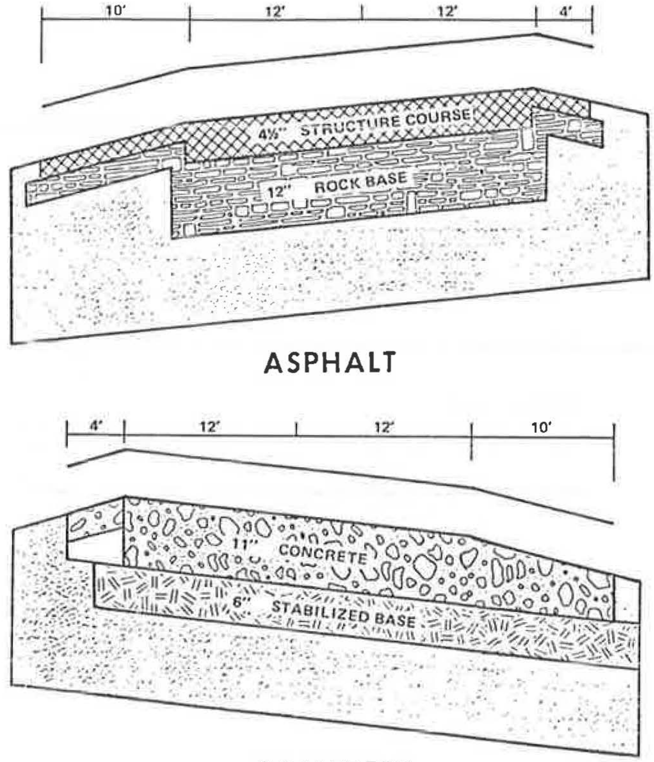


FIGURE 1 Typical sections of alternate pavement designs for initial construction.

PROJECT DESCRIPTION

For cost comparison purposes we selected a typical rural four-lane Interstate project designed to provide adequate capacity and structural strength for the estimated traffic volume for 20 years. It was assumed that after this period traffic would increase through the 30th year until the carrying capacity of the roadway was exceeded and the roadway required major widening and reworking, ending the economic life of the initial roadway. Using current FDOT design procedures, the two pavement designs (asphalt and nonreinforced concrete) shown in Figure 1 were prepared based on the assumption that during the 20-year design period there would be 10 million 18-kip equivalent single axle loads in the design lane. The asphalt pavement design uses a stage construction concept that provides an initial pavement and base thickness sufficient for the first 10-year loadings with a planned second stage pavement layer to be added after the tenth year. The combination of the first and second stage construction provides an asphalt pavement design equivalent to the concrete pavement design.

Based on these designs the quantity of materials required to construct a 1-mile section of Interstate was calculated for each pavement type. Design component costs, given in Table 1, were then estimated based on 1983 prices for similar new Interstate construction projects in Florida.

To determine the total life-cycle cost of equivalent pavement sections, it was assumed that 30 years represents the economic life of a successful project and is an appropriate period of analysis. All major rehabilitative activities and annual routine pavement maintenance expenditures were then estimated as well as the salvage value of the pavement materials in place at the end of the 30-year period. Estimates of the annual expenditures for routine maintenance on each pavement type for the hypothetical 1-mile section were $528 for asphalt and $1,044 for concrete. These estimates were based on the historic expenditure experience of the FDOT for asphalt and concrete Interstate roadways. Terminal values were also estimated using $0 per ton for concrete pavement and $8 per ton for asphalt pavement. These figures are the estimated differences in the cost to salvage old pavements in rural settings and the market value of the recycled material to be used on other projects. Table 1 gives the life-cycle components and their cost estimates in 1983 dollars.

LIFE-CYCLE COST ANALYSIS

This study provides a description of the economic principles, analytic techniques, and primary conclusions reached in performing a life-cycle cost (LCC) analysis of asphalt and concrete pavement designs for a typical rural highway section. Maximizing economic efficiency is the decision criterion implicit in this technique. Therefore, even though other factors may also be important, the pavement design with the lowest LCC would be the most economically efficient choice.

Discounting and Opportunity Cost of Capital

The concept of LCC should be understood to represent an economic assessment of competing design alternatives, considering all significant costs over the life of each alternative, expressed in equivalent dollars (2). A key to LCC is economic assessment using equivalent dollars. For example, assume one person has $1,000 on hand, another has $1,000 promised 10 years from now, and a third is collecting $100 a year for 10 years. Each has assets of $1,000. However, are the assets equivalent? The answer is

TABLE 1 Life-Cycle Components and Cost[a]

Design Element	Asphalt	Cost ($)	Concrete	Cost ($)
Initial construction				
Surface	4½ in. (stage 1)	346,041	11 in. concrete	673,016
Base	12 in. rock	198,940	6 in. sand and stone	92,712
Major maintenance				
10 years	2 in. (stage 2)	219,890	Reseal joints	33,131
20 years	Recycle	179,018	Reseal joints	33,131
Routine annual maintenance		528		1,044
Terminal	7½ in. pavement	94,336	11 in. pavement	0

[a]1983 dollars.

not simple because the assets are spread across different points in time. To determine whose assets are worth most, a baseline time reference must first be established. All dollar values are then brought back to the baseline, using proper economic procedures to develop an equivalent dollar value. Given the time value of money, today's dollar is simply not equal to tomorrow's dollar. Money invested in any form earns, or has the capacity to earn, interest so that a dollar today is worth more than the prospect of a dollar at some future time. The same principle applies when comparing the cost of various pavement design alternatives over time.

Each alternative may have a different stream of costs that must be transformed into a single equivalent dollar value before a meaningful comparison can be made. The rate at which these alternative cost streams are converted into a single equivalent dollar value is referred to as the discount rate.

The time value of money concept applies far beyond the financial aspects of interest paid on borrowed money. First, money is only a medium of exchange that represents ownership of real resources--land, labor, raw materials, plant and equipment--that are diverted from one use to another. Second, the most important concept in the use of a discount rate is the opportunity cost of capital (3-7). The funds expended for a government project are not funds that would otherwise stand idle. They are obtained by the government from the private sector, either by taxation or by borrowing, or from the government itself by diverting funds from other purposes. If left in the private sector, such funds will be put to use there, and in that use will earn a return that measures the value society places on the use of funds. If the funds are diverted to government use, the true cost of the diversion is the return that would otherwise have been earned. The cost is the opportunity cost of capital and is the correct discount rate to use in calculating the LCC of various pavement design alternatives.

Inflation

The issue of how to deal with inflation in LCC studies is important because the procedure adopted for the treatment of inflation can have a decided effect on the results of an analysis. First, the difference between two types of price changes must be carefully identified: general inflation and differential price changes. The former may be defined as an increase in the general level of prices and income throughout the economy. Differential price change means the difference between the price trend of the goods and services being analyzed and the general price trend. During the period of analysis some prices may decline whereas others may remain fairly constant, keep pace with, or exceed the general trend in prices.

Distortions in the analysis caused by general inflation can be avoided by making appropriate decisions regarding the discount rate and the treatment of future costs. The discount rate for performing present-value calculations on public projects should represent the opportunity cost of capital to the taxpayer as reflected by the average market rate of return. However, the market or nominal rate of interest includes an allowance for expected inflation as well as a return that represents the real cost of capital. For example, a current market rate of interest of 12 percent may well represent a 7 percent opportunity cost component and a 5 percent inflation component. The practice of expressing future costs in constant dollars and then discounting these costs using the market, or nominal, rate of interest is in error and will understate the LCC of an alternative. Similarly, the practice of expressing future costs in inflated, or current, dollars and then discounting the costs using the real cost of capital would overstate the LCC of an alternative.

The distortion caused by general inflation may be neutralized in two ways. One is to use the nominal rate of interest (including its inflation premium) for discounting, while all costs are projected in inflated or current dollars. The other is to adjust the nominal rate of interest for inflation, discounting with the real rate component only, while measuring the cost stream in constant dollars. Because of the uncertainty associated with predicting future rates of inflation and in view of the similar results achieved by following either method, a discount rate has been used that represents the real cost of capital while calculating LCC in constant dollars. Because it avoids the need for speculation about inflation in arriving at the economic merit of a project, this procedure is generally accepted in the engineering profession (2,3,6) and is recommended by the U.S. Office of Management and Budget (8).

Although the distortions caused by general price inflation can be easily neutralized, the issue of incorporating differential, or real, price changes into an economic analysis is an extremely complex matter. Authorities such as Winfrey (9,pp.247-248), Lee, and Grant (10,p.253;11) have recommended the use of differential prices only when there is overwhelming or substantial evidence that certain inputs, such as land, are expected to experience significant price changes relative to the general price level. It is the preferred practice, and the one followed in this study, to incorporate differential prices in a separate sensitivity analysis. At the point where a decision is reversed, the differential prices can be carefully examined to determine if there is a high probability that they will prevail.

Comparative Analysis

This section provides a comparative LCC analysis of an asphalt and a concrete pavement design. In line with the previous discussion, differential prices were not included in this phase of the analysis but are fully considered in a separate sensitivity analysis.

Both the expected physical life and the possibility of technological obsolescence serve as upper limit parameters in estimating the life of a project. The critical determinant, however, will be the economic life of the project. The latter is that estimated period of time extending from the date the project is complete and service actually begins to the date when the project is no longer economically viable. With this in mind, 30 years has been selected as the most appropriate period of analysis. However, for comparative purposes a 40-year analysis period is also included.

Selection of a discount rate can be a crucial parameter in LCC analysis. A high discount rate means a lower life-cycle cost for those design alternatives the costs of which are incurred late in their economic life. Similarly, a low discount rate means a much higher life-cycle cost for these same design alternatives. It is believed that the true social opportunity cost of capital, before taxes and after inflation, is approximately 7 percent and this is the correct discount rate to use in an LCC analysis. Predictably, the selection of a discount rate has generated a diversity of opinion (3,8,12,13). Because the results of this analysis may be sensitive to the discount rate used, calculations will be performed at two additional discount rates (5 and 10 percent), which represent the extreme upper and lower range of current opinion.

Computational Formulas

$$PV = IC + (P/F,r,N_2)(STG2) + (P/F,r,N_3)(STG3) + \ldots (P/F,r,N)(STGN) + (P/A,r,N)(AMC) - (P/F,r,N)(TSV)$$

where

PV = present-value cost per mile of concrete or asphalt pavement;
IC = initial cost per mile of concrete or asphalt pavement;
N_i = analysis period (yr);
r = discount rate (5%, 7%, 10%);
STG2 = stage 2 cost per mile, overlay for asphalt pavement, joint resealing for concrete pavement;
STG3 = stage 3 cost per mile recycling for asphalt pavement, joint resealing for concrete pavement;
STGN = final stage cost per mile, recycling for asphalt pavement, joint resealing for concrete pavement;
AMC = annual maintenance cost per mile of either concrete or asphalt pavement; and
TSV = terminal salvage value of asphalt pavement.
$(P/F,r,N_i)$ = Single Payment Present-Worth Factor $= 1/(1 + r)^{N_i}$

where

r = discount rate and
$N_i = N_2, N_3, \ldots N_n$.
$(P/A,r,N)$ = Uniform Series Present-Worth Factor $= [(1 + r)^N - 1]/r(1 + r)^N$

where

r = discount rate and
N = analysis period.

Results of Comparative Analysis

The results of the comparative LCC analysis are provided in Table 2 for the two alternative pavement designs. To test the sensitivity of these results to changes in certain key parameters, two additional discount rates are considered and a 40-year analysis period is included.

TABLE 2 Total Life-Cycle Present-Worth Cost Comparison

	Discount Rate (%)		
Alternative	5	7	10
30-year life-cycle cost ($)			
Concrete pavement	814,603	804,087	793,268
Asphalt pavement	733,734	697,182	655,939
40-year life-cycle cost ($)			
Concrete pavement	824,134	809,402	795,534
Asphalt pavement	782,925	726,527	670,048

Largely because of the use of stage construction, the results indicate a clear and decisive advantage of asphalt over concrete pavement. Note that these results are not sensitive to changes in key parameters. The life-cycle cost of the asphalt pavement design is significantly lower regardless of the discount rate or period of analysis chosen.

Sensitivity Analysis

The issue of incorporating differential, or real, price changes in an LCC analysis is an extremely complex matter. Authorities have recommended the use of differential prices only when there is overwhelming or substantial evidence that certain inputs are expected to experience significant price changes relative to the general price level. The key question is what constitutes "overwhelming evidence"? Overwhelming evidence is interpreted here to mean long-term historic experience, based on an economic phenomenon that is clearly understood and reasonably predictable. There are few examples where there is an indication that the real price of some input is likely to increase over a 30- to 40-year period. It is important to remember that real price increases represent those increases in excess of the general inflation rate.

It is often argued that the real price of land, especially in highly congested areas, has increased over the long term. This is because there is an absolutely fixed supply of land and therefore each successive use intensifies a scarcity problem. Real prices are thus forced up by rising demand.

Another argument is frequently made that energy, in particular petroleum, is a scarce natural resource, limited in supply, that will exhibit real price increases in the future. In addition, the activities of the Organization of Petroleum Exporting Countries (OPEC) cartel, it is believed, will lead to price increases above those expected for a scarce natural resource. Although these arguments provide compelling examples, a closer examination of the energy issue reveals the complexity of trying to anticipate what may happen to the long-term price of petroleum.

First, cartels have historically experienced only short-term success. The prevailing view of OPEC is that it has not yet demonstrated its ability to control prices over a long period of time. Second, although petroleum is recognized as a scarce natural resource, there are mitigating factors, such as new discoveries, technological change, substitution, and conservation (14,pp.129-147) that may moderate price increases. These factors cannot be ruled out on the basis of our recent energy experience.

Although the scarcity argument provides a strong case for believing that the real price of petroleum will increase over the long run, a closer examination of these issues reveals that, given the previous discussion, this may not occur. Even if real price increases for petroleum do occur, predicting their timing and magnitude would be highly speculative.

The case for incorporating differential price changes in a comparative analysis of asphalt and concrete pavements is even weaker and more ambiguous. Certainly the same criterion should be required: long-term historic experience based on a phenomenon that is clearly understood and reasonably predictable. Unfortunately, this criterion presents several problems such as which price index and time period to use as a historic guide. Which period is most appropriate? A variety of different and probably erroneous assumptions about the future is possible depending on the historic period selected.

There are also other problems. The criterion that requires overwhelming evidence before differential prices can be used in LCC analysis still applies. A history of real price changes must be based on an economic phenomenon that is clearly understood before one can reasonably predict that these trends will continue over a 30-year period. Historic price trends, unsupported by an underlying economic rationale, may merely reflect a statistical artifact. Is the underlying basis for real price changes in both asphalt and concrete pavements clearly understood? Certainly the cost of both is inseparably linked to the price of energy, and the price of energy has experienced unprecedented instability during the past decade. Other factors such as demand, industrial structure, and the cost of labor are also important but have obscure and uncertain impacts. All of these conditions make it extremely difficult to predict future price trends; consequently, the criteria for establishing overwhelming or substantial evidence have not been met.

Nevertheless, the purpose of a sensitivity analysis is to determine how sensitive results may be to variations in uncertain parameters. How would differential prices, even if incorporated in this analysis, alter the results? Instead of arbitrarily selecting a historic period as a guide to the future, it was decided to use an established econometric model, Data Resources, Inc. (DRI), to forecast real price trends (15). This approach is more rigorous in that it relies on a model that explicitly contains an underlying economic rationale that can be tested statistically.

Although the DRI forecast does not provide a prediction of the real price changes in asphalt and concrete, the costs of both are inseparably linked to the price of energy. According to Data Resources, the real price of U.S. oil, which will be used as a surrogate for the future price of asphalt, is expected to increase at a compound annual rate of 2.6 percent (15,p.1.118).

The sensitivity analysis was conducted by applying the 2.6 percent escalator to the estimated cost of the asphalt material contained in the stage 2 and the recycling elements of the asphalt pavement design. Of the stage 2 costs ($219,890), $78,840 is asphalt material. Of the recycling costs ($179,018), $14,250 is asphalt material (see Table 1).

Although a real price increase of 2.6 percent may seem small, it is important to remember that real price increases represent those increases in excess of the general inflation rate. Further, the compounding effect of such a price increase over a 30-year period would have a significant effect on the real cost of highway construction. Such a growth rate would provide ample incentive for technological change and substitution. However, the sensitivity analysis has been conducted as if the 2.6 percent real growth rate held over the entire analysis period, 30 and 40 years, and no technological breakthroughs or substitutions occurred to reduce asphalt consumption. Recent studies of the use of sulphur as an asphalt extender or substitute are examples of how technological progress often makes long-term projections based on current technology difficult (16).

Results of Sensitivity Analysis

The results of the sensitivity analysis are presented in Table 3. The purpose of a sensitivity analysis is to identify the turning points in a decision. In particular, the sensitivity analysis should indicate whether the strongest argument for the highest cost alternative is sufficient to change the results of the comparative analysis. In this case the comparative analysis (Table 2) and the sensitivity analysis (Table 3) are in agreement. This strengthens confidence in the results of the comparative analysis.

Both Tables 2 and 3 should be interpreted as efforts to depict the relative confidence that could be placed in making a decision based on a 7 percent discount rate at 30 years. Table 2 indicates that widening the discount range or the project life does not affect the choice. The results indicate a clear and decisive economic advantage to asphalt pavement over concrete pavement in this case study. In Table 3 the life-cycle cost of the concrete pavement alternative is higher under the most extreme parametric assumptions--a 5 percent discount rate at 40 years with a projected 2.6 percent real increase in the price of asphalt material. The results of the sensitivity analysis further confirm the outcome of the comparative analysis.

TABLE 3 Total Life-Cycle Present-Worth Cost Comparison with Escalator

Alternative	Discount Rate (%) 5	7	10
30-year life-cycle cost ($)			
Concrete pavement	814,604	804,087	793,268
Asphalt pavement	750,603	710,637	665,691
40-year life-cycle cost ($)			
Concrete pavement	824,135	809,402	795,534
Asphalt pavement	803,618	742,153	680,157

ECONOMIC IMPACT ANALYSIS

An implicit assertion, on behalf of the cement and concrete industry, is that the use of concrete pavement in highway construction generates a significantly greater local earnings and employment impact than does the use of asphalt (1). Two lines of reasoning are generally offered in support of this assertion. First, concrete highway construction is more labor intensive than asphalt construction. Second, whereas asphalt is an essential component of imported petroleum, all cement and concrete products are locally produced and therefore their use has a greater economic impact.

Elected officials often find these assertions compelling because the employment impact of public investment may be considered more important than achieving economic efficiency, especially during periods of economic contraction. Unfortunately, the issue is seldom approached quantitatively except in the most casual manner. An empirical evaluation of the earnings and employment impact of these two designs could substantially improve public decision making by removing some of the ambiguity surrounding this issue.

Regional Input-Output Modeling System

This type of economic assessment has previously required the development of an input-output model that was complex, time consuming, and expensive to construct. Recently these problems have been overcome with the development of the Regional Input-Output Modeling System (RIMS II) by the Regional Economic Analysis Division of the Bureau of Economic Analysis (BEA), U.S. Department of Commerce (17). The RIMS II provides region-specific multipliers for a single county or groups of counties and industry-specific multipliers for any of the 496 industrial sectors contained in the 1972 BEA national input-output table. These multipliers are obtained by a standard and consistent methodology at reasonable cost and permit the estimation of the relative impact of investing in either asphalt or concrete highway construction projects.

RIMS II provides earnings multipliers that may be used to estimate the employment impact of projects. The model also provides a table of direct coefficients and a table from which output multipliers can be calculated for each industry. However, for public decision purposes, earnings and employment effects are the most appropriate indicator of economic activity.

Methodology and Results of Impact Analysis

There are computational problems associated with the application of the RIMS II input-output model to this public investment issue. The two industries involved are not separate and uniquely defined industries in the RIMS II model. Consequently steps had to be taken to differentiate asphalt highway construction from cement concrete highway construction because each type of construction activity represents unique goods and services.

To account for these differences, the construction cost of each design was disaggregated into various input cost categories based on the FDOT contract estimating system (CES). This computerized system estimates material, equipment quantities, and prices and establishes task and crew configurations, providing the scope of work and production rate for each item (18). It provides the data a hypothetical contractor would need to bid each potential construction contract. Based on information from the CES, the estimated cost of each design (see Table 1) was disaggregated into the following broad input categories consistent with the RIMS II model: highway construction labor cost; the cost of highway construction equipment; and the cost of asphalt, lime rock, and portland cement concrete.

The following step-by-step procedure was used to estimate the earnings and employment impact of the two pavement designs for the 30-year analysis period.

1. Because of its uncertain geographical distribution, and estimated profit/overhead margin of 25 percent embedded in the cost of construction (Table 1) was viewed as a leak from the Florida expenditure-earnings stream and was therefore removed. It should be noted that this adjustment affects all input categories equally; therefore the outcome of the comparative analysis of the two industries is not affected. Because the cost of annual routine maintenance was inconsequential, it was excluded from the impact analysis.

2. The adjusted cost of construction for each pavement design was distributed among the five input cost categories. In terms of input-output analysis the expenditures in each category represent a change in final demand.

3. The adjusted cost of each category was deflated to 1972 dollars (using implicit price deflators for Gross National Product). This step is necessary because the RIMS II model is based on the 1972 National Input-Output model and the various activities under study may have experienced different price changes during that period. To use 1983 dollars could introduce a systematic error into the computations.

4. The cost of each category (1972 dollars) was multiplied by the corresponding RIMS II earnings multiplier and then summed to yield an estimated total earnings impact for each pavement design and for each year in which the expenditure would be made (years 1, 10, and 20).

5. Using BEA personal income data, employment effects were estimated by dividing the total earnings impact for each pavement design (in the year expenditures were made) by the 1972 Florida average annual earnings per employee ($7,385).

The outcome of these calculations is given in Table 4. The cost of construction (1983 dollars); earnings (1972 dollars); and number of persons employed for a 1-year period, full-time equivalent employment (FTE), are reported for each pavement design. In the first year, the concrete pavement design has a greater absolute employment impact (30.9 versus 18.7) and a 17.6 percent greater employment impact per $10,000 of construction cost. During the total 20-year construction period, concrete pavement has a much smaller absolute employment advantage (34.3 versus 31.4) but a slightly larger employment impact (24 percent) per $10,000 of construction cost. To a public decision maker interested in employment impacts, the short-run, first-year impact would be more significant.

TABLE 4 Estimation of the Earnings and Employment Impact of the Two Pavement Designs

Pavement Type	Cost ($)[a]	Earnings ($)[b]	FTE Employment	FTE Employment Cost (per $10,000 construction)
Year 1				
Asphalt	544,981	137,966	18.7	3.4
Concrete	765,728	228,411	30.9	4.0
Year 10				
Asphalt	219,890	47,151	6.4	2.9
Concrete	33,131	12,734	1.7	5.1
Year 20				
Asphalt	179,018	46,824	6.3	3.5
Concrete	33,131	12,734	1.7	5.1
Total				
Asphalt	943,889	231,941	31.4	3.3
Concrete	831,990	253,879	34.3	4.1

[a]Cost in 1983 dollars.
[b]Earnings in 1972 dollars.

There are, however, several important limitations in using this type of model to determine the impact of construction expenditures during a 20-year period. Input-output models, such as RIMS II, are unable to adequately handle substitution effects. Although Conway (19) has demonstrated that changes in technical coefficients during 5- to 10-year time periods are small, the reliability of these coefficients when used over much longer time periods must be viewed with caution. In addition, unlike LCC analysis, input-output models do not account for society's collective rate of time preference that relates the value of some future benefit to the value of an equivalent benefit available today. Consequently there is uncertainty about what value to place on future earnings and employment. Therefore Table 4 must be viewed from an interpretive, judgmental perspective. The missing concept, which is captured by LCC analysis through discounting, must be supplied subjectively by the reader.

Despite these limitations, input-output models are appropriate tools for this type of analysis. They allow the analyst to focus on one particular economic activity and capture the fully multiplied impact of alternative public spending decisions on a regional economy.

Nevertheless, there are several unresolved problems in interpreting the outcome of this analysis. First, the model employed does not distinguish directly between these two pavement designs. The process of interpreting data and assigning cost estimates to given industries is a source of imprecision. Second, the data used are estimates and are a second source of imprecision. Third, although the outcome of the analysis favors concrete, there is no decision rule in impact analysis comparable to that of LCC analysis where the lowest cost pavement design is considered the most economically efficient choice. Therefore, decision makers must apply interpretive judgment to the value of these conclusions.

Although the model and analytic approach have the capacity to discriminate between two products, the results are not entirely conclusive because of these problems. Nevertheless, these results are useful for dismissing the argument that either product has a significantly larger economic impact than does the other.

This has been a limited analysis. A larger research effort, beyond the scope of this paper, may find this analysis more useful when balanced among a wider range of topics such as business-cycle policy, economic efficiency arguments, and agency budget constraints.

CONCLUSIONS

In this particular study, using specific designs for a hypothetical rural Florida project and 1983 Florida estimated costs, the asphalt pavement design was the clear and unambiguous economic choice at 5, 7, and 10 percent discount rates and for both 30- and 40-year project lives. A sensitivity analysis of energy price impacts was conducted by assigning asphalt material prices a 2.6 percent differential inflation rate. The asphalt pavement design was again the economic choice in all comparisons.

An economic impact analysis, which consisted of an assessment of the earnings and employment effects of each design, was accomplished by applying an input-output model, RIMS II, to industry-specific input costs. The study found an employment benefit in the use of concrete; however, the interpretation of this advantage must be left to the decision maker. Further research is recommended.

A comparative life-cycle cost analysis should be conducted routinely. It has great potential for resolving ambiguous public debate as well as for maximizing the economic efficiency of public expenditures.

ACKNOWLEDGMENT

Special recognition is given to Joseph V. Cartwright, U.S. Department of Commerce, for his guidance in the use of the RIMS II input-output model and to Gregory Miller, Governor's Office, State of Florida, for his comments and support in reviewing this paper.

The contents of this paper reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views of the Florida Department of Transportation.

Discussion

Robert Roy and Gordon K. Ray*

The paper by Sandler, Denham, and Trickey of the Florida Department of Transportation is an example of how life-cycle cost analysis can be applied to the evaluation of alternate pavement types, namely asphalt and concrete. Unfortunately, although they have correctly applied the life-cycle cost technique in a technical sense, several of their assumptions that are critical to the whole analysis are subjective and far removed from economic or engineering reality. This discussion will focus on three assumptions:

1. The choice of the appropriate real discount rate,
2. The choice of the appropriate time span between resurfacings of asphalt pavements, and
3. The choice of a salvage value for concrete pavements.

The word "choice" is stressed because there are no fixed, immutable assumptions in life-cycle cost analysis. Alternative calculations will be presented later using different assumptions than those used by Sander et al. The outcomes are substantially different--the life-cycle cost of the concrete pavement design is lower than asphalt in virtually every instance.

THE "REAL" REAL DISCOUNT RATE

Sandler et al. have not considered actual real interest rates (i.e., adjusted for inflation) at all in their paper, let alone real interest rate trends over the past three or four decades. They assume a real discount rate (or a range of real rates) with no empirical justification. Considering the actual course of inflation and interest rates during the past 30 years, the conclusion is clear--the "real" real discount rate is much lower than Sandler et al. assume.

Although there is some controversy among monetary economists about whether real interest rates are constant over time, there is almost total agreement among them that the expected real rate of interest

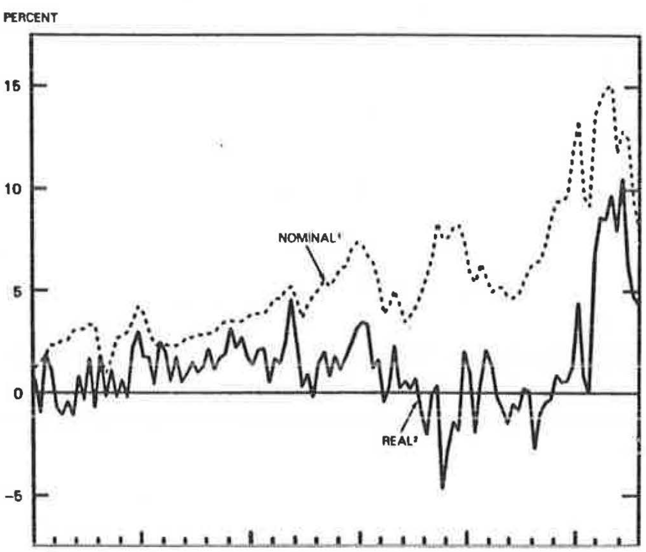
*Robert Roy is Chief Economist and Gordon K. Ray is Director of the Paving and Transportation Department, Portland Cement Association, Skokie, Illinois.

virtually always falls between 0 and 4.5 percent, with a typical value somewhere between 1 and 2.5 percent. This range holds regardless of how inflation is measured, of which particular interest rate is chosen, or of whether current inflation is compared with future or current interest rates. It holds regardless of the time period under consideration--before World War I, between the Wars, after World War II, or since 1970.

Real interest rates have been negative at times in the past, and, of course, they have been quite high recently, but these are temporary phenomena resulting from the sluggish adjustment of market interest rates to a lasting change in inflation. After a period, if a change in the inflation rate proves to be permanent, market interest rates adjust along with inflationary expectations. The real interest rate reverts back to its longstanding historical range.

EXAMPLE

In this example the real interest rate has been calculated by subtracting the price deflator for personal consumption expenditures from the 91-day U.S. Treasury bill (T-bill) rate (see Figure 2). The data are reported on a quarterly basis at a compound annual rate. This measure of inflation comes from the GNP accounts computed by the U.S. Department of Commerce and is widely considered to be one of the best overall measures of inflation. The 91-day T-bill rate is used because of its quarterly maturity. Data were collected from the first quarter of 1956 to the first quarter of 1983, or 112 quarters (28 years).



¹CONVERTED TO EFFECTIVE ANNUAL YIELD FROM DISCOUNT BASIS.

²EQUALS NOMINAL YIELD LESS ACTUAL RATE OF INFLATION, DEFINED BY PERSONAL CONSUMPTION DEFLATOR, OVER THE PERIOD TO MATURITY. DEFLATOR FOR FIRST QUARTER 1983 FORECAST BY COUNCIL OF ECONOMIC ADVISERS.

SOURCES: DEPARTMENT OF COMMERCE, BOARD OF GOVERNORS OF THE FEDERAL RESERVE SYSTEM, AND COUNCIL OF ECONOMIC ADVISERS.

FIGURE 2 Nominal and real 3-month Treasury bill yield.

The real T-bill interest rate as calculated here ranged from a low of negative 4.7 percent in the first quarter of 1974 to a high of 8.4 percent in the second quarter of 1982. The average real T-bill rate was 1.2 percent in this 28-year period with a standard deviation of 2.2 percentage points. The real T-bill rate had no statistically significant trend either upward or downward. Standard confidence tests indicate that the following outcomes could be expected:

Future Time Frame	Number of Quarters the Real T-Bill Rate Is Expected to Exceed			
	4.1%	4.9%	6.4%	7%
100 quarters or 25 yr	10	5	1	0.5
120 quarters or 30 yr	12	6	1.2	0.6
160 quarters or 40 yr	16	8	1.6	0.8

Thus, from the standpoint of probability, one would expect the real T-bill rate to exceed 4.1 percent only 16 times in the next 160 quarters (or 40 yr) and to exceed 6.4 percent only once or twice. One would expect the real T-bill rate to surpass 7 percent only one quarter every 50 years. This example and common sense indicate that current real interest rates will not and cannot persist for long. Yet, Sandler et al., without any empirical prototype use real discount rates of 5, 7, and 10 percent.

It might be argued that past economic relationships give no guide to the future, but this is a faulty assumption. There are fundamental inconsistencies in today's economy that cannot continue unresolved. The economy cannot keep expanding with abnormally high real interest rates. Either market interest rates must decline or inflation must increase, and, if the latter were to occur, the expansion still would not last. In either case real interest rates will decline to their historical range of 0-4.5 percent. Certainly, when evaluating a public project with an expected life of 30-40 yr, it would not be appropriate to challenge an empirical relationship that has been validated as far back as the nineteenth century just because of a few abnormal quarters in 1981 and 1982.

TIME INTERVAL TO FUTURE EXPENDITURES

A second factor that can distort life-cycle costs is the assumption of unrealistic time intervals until future expenditures are made. Because the effect of applying a discount rate is to reduce the present value of future costs, the longer costs are deferred, the lower the discounted present value.

Sandler et al. assume that flexible pavement will have a second stage applied in 10 yr and be recycled at 20 and 30 yr. This assumption greatly understates the cost of these future expenditures. In a communication to the Legislative Transportation Committee, the Florida Department of Transportation documented that the weighted average age to second stage for Florida Interstate flexible pavements was 6.3 yr. Confirming this was a study conducted by the Portland Cement Association in 1983 of all Interstate highways in Florida, both flexible and rigid, showing that the weighted average interval of flexible pavements to overlay (either second-stage or major maintenance resurfacing) was 6.4 yr.

TERMINAL VALUES

Also significant in the life-cycle cost analysis are the estimates by Sandler et al. of terminal values of material for recycling of $8 per ton for asphalt pavement and $0 per ton for concrete pavement. Both airport and highway concrete recycling projects throughout the nation indicate that $4 per ton for old concrete would be more realistic.

NEW RESULTS

Table 5 has been prepared to correspond with Table 2

TABLE 5 Alternative Total Life-Cycle Present-Worth Cost Comparison

	Discount Rate (%)					
	7		3		0	
Alternative	FDOT Analysis[a]	Revised Analysis[b]	FDOT Analysis	Revised Analysis	FDOT Analysis	Revised Analysis
30-year life-cycle cost ($)						
Concrete pavement	804,087	804,087	829,265	790,790	863,310	769,922
Asphalt pavement	697,182	826,042	779,160	975,091	865,403	1,154,919
40-year life-cycle cost ($)						
Concrete pavement	809,402	803,166	846,506	817,877	906,881	813,493
Asphalt pavement	726,527	865,649	860,900	1,076,322	1,037,000	1,414,609

[a]10-yr flexible major maintenance cycle, $0/ton for recycled concrete.

[b]6.4-yr flexible major maintenance cycle, $4/ton for recycled concrete.

in the Sandler et al. paper. The real discount rate selected by Sandler et al. of 7 percent is shown, but rates of 3 and 0 percent are also shown. The 3 percent real discount rate represents the upper limit based on the historical record even when risk factors and administrative costs are added. The 0 percent real rate represents the rate selected by many state highway departments that use neither imputed interest nor inflation; the figures shown for 0 percent are simply the undiscounted, estimated dollar expenditures over the analysis period.

Under each discount rate in Table 5, column 1 is calculated using the same assumptions for all costs and time periods that were used by Sandler et al. With the 7 percent discount rate chosen by Sandler et al., the asphalt pavement design is shown to have the lower life-cycle cost. However, when a more realistic 3 percent real discount rate is used, the 40-yr analysis favors the selection of concrete. When a 0 percent real discount rate is used, both the 30- and 40-yr analyses favor concrete.

When a more realistic overlay cycle of 6.4 yr is used for asphalt and a recycling value of $4 per ton is attributed to old concrete, the figures in column 2 are derived. Although the routine maintenance costs used by Sandler et al. are questionable, they have been used again. The Sandler, Denham, and Trickey paper states that annual routine maintenance expenditure by Florida DOT for asphalt is $528 per mile and $1,044 for concrete "based on historical expenditure experience." In contrast, a 1984 Florida DOT letter in response to a Legislative Transportation Committee inquiry stated: "In regard to your request we have been reviewing cost data available in the department with respect to asphalt pavement and cement concrete pavement maintenance... I regret to say the systems currently in place in the department do not collect data to the detail necessary to determine life-cycle costs of pavements on a statewide basis." Under circumstances similar to these, it appears that a better procedure may be to avoid using undocumented maintenance costs. In this case, concrete becomes the preferred selection for both the 30- and 40-yr analyses, not only for 0 and 3 percent real discount rates, but even for 7 percent.

CONCLUSION

Life-cycle cost analysis is an excellent way to evaluate alternative public investments or available options for a particular public investment. However, this technique is highly sensitive to the assumptions that are made. The analysis of alternative pavement designs--concrete versus asphalt--by Sandler et al. is one example of the pitfalls of calculating life-cycle costs using inappropriate assumptions for real discount rates, costs (e.g., value of material for recycling and routine maintenance), and time intervals to future expenditures. Only if reasonable, well-documented, and empirically valid assumptions are made can the procedure maximize the economic efficiency of public investments.

Authors' Closure

The purpose of our paper was to demonstrate, within the context of a practical case study, how a life-cycle cost (LCC) comparison of alternative pavement designs should be conducted. Although Robert Roy and Gordon Ray acknowledge that LCC analysis is an excellent technique to apply to questions of pavement design and selection, they take issue with several critically sensitive arguments in our example. They are correct in highlighting the importance of choice in the assumptions used in our model, but the burden of proof is a two-edged sword that applies to their arguments as well as ours. We appreciate the opportunity to extend this discussion and thereby demonstrate that our assumptions were, in fact, reasonable, well documented, and empirically valid.

APPROPRIATE REAL DISCOUNT RATE

Despite the extensive literature on the subject, the comments of Roy and Ray on the discount rates we used in our analysis dramatically illustrate the confusion that still exists about the selection of an appropriate rate. To shed light on this issue, it may be useful to restate what the discount rate represents.

The funds expended for government projects are not funds that would otherwise stand idle. They are obtained by the government from the private sector. If left in the private sector, they will earn a return that measures the value society places on the funds. If the funds are diverted to government use, the true cost of the diversion is the return that would otherwise have been earned. This is the opportunity cost of capital and is the correct rate to use in life-cycle cost analysis.

The critical question is what market rate (or rates) of return on investment in the private sector best measures the opportunity cost of capital to be used in evaluating public projects. This is a complex issue because it involves market imperfections, risk, and the distortion arising from the corporate income tax. All of these considerations should be taken into account in determining the cost of capital.

In our view, the real interest rate suggested by

Roy and Ray, which is frequently calculated by subtacting the rate of inflation from the yield on some short-term security, is not appropriate because it does not, in any sense, represent an average rate of return on private investment. A better measure would be some weighted average yield on private claims against physical assets. This weighted estimate should include a mix of debt and stockholders' equity, including proprietorships and owner-occupied housing.

We were criticized for using a range of discount rates (5, 7, and 10 percent) without supporting empirical evidence. Although it is quite difficult, in practice, to estimate the average rate of return on private investment, an abundance of such evidence does exist. J. Stockfisch not only offers empirical evidence but also includes an excellent discussion of the theoretical issues (20). Gorman (21), Holland and Myers (22,p.151) provide additional empirical work. All of their estimates are close to the upper range of rates we used and are also consistent with those discount rates used by many federal agencies to evaluate public projects (8;13;23;24,p.A-4).

TIME INTERVAL TO FUTURE EXPENDITURES

The purpose of our study was to undertake an economic comparison of candidate pavement designs, not an economic analysis of the outcome of previous pavement design decisions. We were not concerned so much with measuring how well the FDOT had done, as with predicting the relative impact of current decisions. The FDOT's historical experience with pavement types was reflected in our candidate design standards, which were intended to improve on and not repeat the historical experience.

If, however, historical data had been used for asphalt, they should also have been used for concrete. Unfortunately, an excessive reliance on historical performance can often bias the outcome of an analysis. Florida has had only limited experience with designs using concrete pavement on rural highways. Such pavements have exhibited a great deal of variation in performance; consequently, any measure of average performance would have been unduly influenced by such major projects as Interstate 10, which is currently experiencing premature distress. If we had used the historical performance for both designs, the concrete alternative would have been dramatically penalized. For these reasons, we used asphalt resurfacing periods and concrete pavement life periods consistent with the best current design standards.

TERMINAL VALUES

At the time of our analysis, we were unable to establish a market value for recycled concrete. Because of changing technology there may now be recycling projects throughout the nation where, because of local circumstances, a market value for concrete can be established. Certainly, the parameters used in our analysis will be subject to changes over time. For example, we now understand that the value of recycled asphalt may be much higher than the $8 per ton we used in the original analysis. A far more important point is that, given the other assumptions that are much more critical, the outcome of this comparative analysis is not sensitive to the $4 per ton change in terminal value proposed by Roy and Ray.

In conclusion, our original purpose was to encourage consideration and application of life-cycle costing in questions of pavement design selection. We hope we have achieved that intent. We also appreciate the fact that our stated purpose and space constraints did not provide an opportunity for a full presentation of all the supporting empirical evidence, arguments, interpretations, and assumptions of the larger study. The issues raised by Roy and Ray are certainly relevant to the application of the life-cycle cost technique, and we hope that this extended discussion has demonstrated that the assumptions made in this particular case study were reasonable, can be well documented, and are empirically valid.

REFERENCES

1. A Comparative Analysis of Asphalt and Cement Concrete. Florida Department of Transportation, Tallahassee, Fla., 1983.
2. A.J. Dell'isola and S.J. Kirk. Life Cycle Costing for Design Professionals. McGraw-Hill, New York, 1982.
3. A Manual for User Benefit Analysis of Highway and Bus Transit Improvements, 1977. AASHTO, Washington, D.C., 1978.
4. E. Stokey and R. Zeekhauser. A Primer for Policy Analysis. Norton, New York, 1978.
5. R.A. Musgrave and P.B. Musgrave. Public Finance in Theory and Practice. 3rd ed. McGraw-Hill, New York, 1980.
6. R.F. Mikesell. The Rate of Discount for Evaluating Public Projects. American Enterprise Institute for Public Policy Research, Washington, D.C., 1977.
7. W.J. Baumol. On the Social Rate of Discount. American Economic Review, Sept. 1968, pp. 788-802.
8. Discount Rates to be Used in Evaluating Time Distributed Costs and Benefits. Revised Circular A-94. Bureau of the Budget, Executive Office of the President, Washington, D.C., March 1972.
9. R. Winfrey. Economic Analysis for Highways. International Textbook Company, Scranton, Pa., 1969.
10. E.L. Grant, W.G. Ireson, and R.S. Leavenworth. Principles of Engineering Economy. 6th ed. McGraw-Hill, New York, 1976.
11. R.R. Lee and E.L. Grant. Inflation and Highway Economy Studies. In Highway Research Record 100, HRB, National Research Council, Washington, D.C., 1965, pp. 20-37.
12. B.M. Fraumeni and D.W. Jorgenson. Rates of Return by Industrial Sector in the United States, 1948-76. American Economic Review, May 1980, pp. 326-330.
13. U.S. Department of Energy. Federal Energy and Planning Programs: Methodology and Procedures for Life Cycle Cost Analysis. Final rule. 10 C.F.R., Part 436, Nov. 18, 1981.
14. C.W. Howe. Natural Resource Economics. Wiley, New York, 1979.
15. U.S. Long Term Review. Data Resources, Inc., n.p., Winter 1982-83.
16. Sulphur Extended Asphalt Base Evaluation. U.S. Department of Transportation, Federal Highway Administration, Washington, D.C., 1980.
17. Regional Input-Output Modeling System: Estimation, Evaluation and Application of a Disaggregated Regional Impact Model. Regional Economic Analysis Division, Bureau of Economic Analysis, U.S. Department of Commerce, Washington, D.C., 1981.
18. Z. Hergsman, W. Coons, and T. Rothrock. Study of Techniques for Inflation Forecasting and Applications to Florida DOT Programs. Depart-

ment of Civil Engineering, University of Florida, Gainesville, May 1983.
19. R.S. Conway. Changes in Regional Input-Output Coefficients and Regional Forecasting. Regional Science and Urban Economics, March 1980, pp. 153-171.
20. J. Stockfisch. Measuring the Social Rate of Return on Private Investment. In Discounting for Time and Risk in Energy Policy, R. Lind, ed., Johns Hopkins University Press, Baltimore, Md., 1982, pp. 257-272.
21. J.A. Gorman. Nonfinancial Corporations: New Measures of Output and Input. Survey of Current Business, March 1972, pp. 21-27, 33.
22. C.M. Holland and S. Myers. Trends in Corporate Profitability and Capital Costs. In The Nation's Capital Needs, R. Lindsay, ed., Committee for Economic Development, New York, 1979.
23. Economic Analysis of Investment and Regulatory Decisions--A Guide. Report FAA-APO-82.1. Federal Aviation Administration, 1982.
24. Engineering Circular 1105-2-128. U.S. Army Corps of Engineers, Feb. 29, 1984.

Publication of this paper sponsored by Committee on Application of Economic Analysis to Transportation Problems.

Abridgment

Economic Analysis of Highway Investment: Recent Developments in Great Britain

A. D. PEARMAN and K. J. BUTTON

ABSTRACT

The problem of evaluating and assigning priority to proposed highway investments continues to pose difficulties, especially in an era of constrained highway budgets and increasing environmental awareness. In this paper recent developments in the economic analysis of highway investment in Great Britain are described. In Great Britain in the late 1970s, a major government inquiry (the Leitch Committee) criticized several elements of the Department of Transport's investment evaluation procedures. Particular attention was given to traffic forecasting methods, the treatment of uncertainty, the use of design standards, and the balance between economic and environmental impacts. The nature of these criticisms is described together with changes they have induced.

Formal economic analysis has for some time been an important input to the decision-making process for highway investment decisions in Great Britain. It has not, however, been without its critics, and in the late 1970s the pressure of criticism grew so great that the government was forced to institute a committee of inquiry into the procedures adopted for assessing major highway proposals. The committee, chaired by Sir George Leitch and usually referred to as the Leitch Committee, has now published its findings (1). The purpose of this paper is to outline the questions asked by the Leitch Committee, to summarize the conclusions it reached, and to assess present British practice in light of the committee's views.

HIGHWAY INVESTMENT APPRAISAL BEFORE THE LEITCH REPORT

Since 1973 COBA, a computer software package for highway cost-benefit analysis, has formed the main underpinning of official appraisal procedures in Great Britain. COBA uses discounted traffic costs and benefits and probably represents the major regular application of cost-benefit techniques for public policy making in any sector in Great Britain. Despite its widespread use, COBA is by no means a comprehensive evaluation tool, a weakness that was particularly germane to the Leitch Committee's deliberations and to the continuing debate on highway appraisal procedures.

Within the framework of Department of Transport (D. Tp.) appraisal procedures, it is useful to identify two components: the inputs to the economic appraisal and the appraisal itself.

Inputs to the Economic Appraisal

There are two particularly influential inputs to the economic appraisal--forecasts of traffic levels and the specification of the scale and detailed design of the proposed highway. The latter depended at the time of the Leitch Committee's investigations on sets of design standards. D. Tp. policy was to plan for the forecast traffic levels 15 years after the opening of a scheme. Some changes have subsequently been made in the specification and use of design standards. These will be discussed in the third section.

The primary input to the economic appraisal is undoubtedly the forecast of traffic levels, because they have a major influence on both capital costs and potential user benefits. Because of the complex planning and consultation procedures required by each scheme, which can take up to 15 years, and because economic appraisal is based on forecasts 30 years after opening, very long-run traffic forecasts are required. The controversy that surrounded those forecasts is discussed elsewhere (2).

Economic Appraisal

The structure of the software package COBA has not significantly changed in the wake of the Leitch Committee report. D. Tp. has taken the view that, apart from costs directly related to the construction process, the only impacts of a road scheme that can be estimated sufficiently accurately to justify their inclusion in a formal cost-benefit calculation are savings in travel time and vehicle operating costs and accident cost savings.

Time savings are separated in COBA into savings of working time and nonworking time. Together they constitute the major benefit for most interurban road schemes (typically about 80 percent of the total). Working time is valued at its cost (wages plus overhead) to the employer on the grounds that the time saved may be used to contribute to further output, thus benefiting the community as a whole. Savings on nonworking time cannot, of course, be directly evaluated. Before the Leitch Report, D. Tp. had concluded that it would be reasonable to use 25 percent of the average wage rate as a value for leisure time savings. No distinction was made between people with different wage rates. An "equity value" was used, implying the value judgment that all people's leisure time ought to be valued equally, irrespective of their income.

Accident cost savings are assessed on the basis of cost estimates for accidents of given grades of severity. They contain allowances for lost output; medical, ambulance, police, and damage costs; and a notional allowance for the pain, grief, and suffering of victims and relatives. The value of the output of those killed is taken as the discounted value of their expected future earnings. Before Leitch, the values incorporated for pain, grief, and suffering were "guesstimates," biased toward minimum values.

Vehicle operating cost savings include fuel, oil, tires, vehicle maintenance and depreciation (as it relates to use rather than time). Typically, however, operating cost savings do not contribute greatly to the overall benefit of a scheme.

Each scheme input to COBA is evaluated relative to a "do-nothing" alternative. COBA uses a test discount rate (currently 7 percent) fixed by government policy in valuing future costs and benefits, and selection between competing schemes is based on incremental cost-benefit analysis. Clearly there is a wide range, both of benefits and of costs, that is not reflected in the COBA appraisal framework. Some of these benefits and costs were, however, recognized and assessed, although not in the rigorous, quantitative fashion just described. The two that were explicitly considered were regional economic development benefits and environmental factors. The problem of environmental evaluation had been considered in 1976 by the Jefferson Committee (3). The committee argued that it was impracticable to include such factors formally within a cost-benefit analysis, but that D. Tp. should adopt a standard format for their presentation.

How the final priority ranking of schemes was done, given the formal economic analysis of COBA and the more qualitative assessment of regional and environmental impacts, was something of a mystery to the Leitch Committee. D. Tp. stated that the final assessments were made centrally by the department, that schemes with higher economic returns were given higher priority, but that this was by no means the only consideration.

RECOMMENDATIONS OF THE LEITCH COMMITTEE

Inputs to the Economic Appraisal

The committee made relatively little detailed comment about design standards, but it did recognize the important interdependence of design and appraisal. To this end, it expressed the view that D. Tp. should be less rigid in its use of design standards and more willing to use cost-benefit appraisal of alternatives as a basis for selecting highway designs. It was therefore important that the overall evaluation framework be consistent with both its use as a design tool and its use for guiding decentralized minor decision making--notably in terms of the running cost of the associated computer programs.

Numerous criticisms were received about the insubstantial theoretical backing for the use of a logistic time trend projection model for the crucial forecasting of car ownership, about the calibration technique employed, and about the continuing inconsistency between official forecasts of car ownership and actual ownership. In light of the evidence, the Leitch Committee stated that "the Department should as soon as it is practicable move away from the extrapolative form of model currently used towards basing its forecasts on causal models" (1). They recommended that in the future attention be given to the forecasting of car use instead of car ownership, and since then a number of attempts have been made to develop direct, single-stage models of use [see, e.g., (4)]. The committee also recommended that "the Department should indicate the likely range of uncertainties involved in the forecasts and demonstrate the consequences of selecting different values within that likely range" (1).

Economic Appraisal

The implication of this last recommendation for traffic forecasting was that the cost-benefit analysis, however it might be undertaken, could no longer rely on a single series of figures. This issue is discussed later. Of more immediate interest are the views of the committee on COBA and on the balance struck between the output of COBA and the regional and environmental assessments.

The committee recognized that much of the disquiet about appraisal procedures could be traced to the fact that COBA was a partial assessment procedure. The committee recognized, however, that many of the items relevant to a comprehensive assessment were beyond reliable evaluation in monetary terms for the foreseeable future. The committee argued therefore that the best solution attainable was to require that the impacts of each proposed scheme be set down within a framework of the planning balance sheet type, embracing both economic and environmental factors. Impacts would be assessed for five initial incidence groups--road users directly affected, nonroad users directly affected; those concerned with the intrinsic value of the area; those indirectly affected; and the financing authority. This would permit some (albeit crude) statements to be made about the distributive effects of schemes.

Within the framework, where an economic evaluation proved impossible, a numerical index, or a ranking across alternative schemes, or even a verbal description is inserted. In this way the comprehensive representation of all types of effects is encouraged. It was recognized that the preparation of a framework of this type would increase the cost of appraisal somewhat, but because design and appraisal typically accounted for only 3 percent of total scheme costs, it was believed that a small increase would not cause great problems and could yield considerable benefits. In principle it would be possible to use the entries in the framework to conduct a formal multiple criteria analysis. This was not believed to be a practicable proposition, however. Instead the committee argued that the framework should be used as a basis for judgment.

The Leitch Committee also made a number of other, more detailed comments about the economic appraisal process and about COBA in particular, which it did not intend to abandon but merely planned to subsume within the wider framework. It was believed that the specific inclusion of regional development effects was not generally justified. It was also the view of the committee that the "equity value" associated with nonwork travel time was inconsistent with the theoretical basis of cost-benefit analysis and should be abandoned. A distinction should be made, too, between savings of journey-to-work time and other nonwork travel time. Accident costs were regarded as properly treated in principle, except for the evaluation of pain, grief, and suffering. Here it was agreed that use of a minimum figure was inappropriate to a cost-benefit analysis. The minimum figure should be replaced by a central estimate.

CONSEQUENT CHANGES IN APPRAISAL PRACTICE

One significant change that has been made concerns car ownership forecasts. D. Tp. believes that, with the modeling capability currently at its disposal, it cannot realistically forecast a range of possible traffic levels that spans the next 30 years or more with probability assessments attached to different parts of the range. Instead it has published two separate traffic projections, one "high," one "low." The two sets of projections, although they have a foundation in formal modeling, are neither maximum nor minimum levels nor 95 percent confidence levels but merely figures against which it would be prudent to plan. These figures are based ultimately on the subjective views of D. Tp. officials. Although this state of affairs may be a tolerable short-term response to a request for a major change in official practice, it clearly cannot be held to be satisfactory in the long run.

In other respects D. Tp. has reacted more constructively to the Leitch Committee criticism of its failure to allow for uncertainty. One particularly interesting line of investigation (5) had as its aim the identification of the main sources of error in transport models. The implication is that once the more sensitive inputs can be identified, greater concentration can be placed on ensuring the maximum possible accuracy in those places in the modeling sequence where it matters most. The work was done using a Monte Carlo simulation exercise.

It was recognized, however, that the computational requirements of a Monte Carlo simulation were too great to permit its use as standard practice. What has now evolved (6) is a method, based on experimental design techniques, that is far more economical of computer time. Such a procedure would probably require a fourfold increase in processing time, which, relative to the overall costs of a highway investment, is not a great demand. Nevertheless, at present D. Tp. appears unwilling to make a commitment, arguing not only direct financial considerations but also lack of trained manpower.

In many respects it is impossible at this stage to assess the full impact of the Leitch Report on highway appraisal in Great Britain. This is in part because not enough time has passed, but it also reflects the fact that a change in government policy has switched emphasis away from some of the more contentious types of highway proposal toward generally less sensitive issues, such as bypassing small and congested historic towns.

Thus the highway debate has diminished in intensity, but arguably it is not the Leitch Committee that has dispersed the problems. It appears that a change in attitude toward greater openness and comprehensibility in planning procedures may have been instigated, but some would argue that the crucial question, which was not formally within the committee's terms of reference--how does society decide on the type of highways to plan--is the one that is really most needed and still needs to be answered.

CONCLUSIONS

A summary of a series of interesting changes in attitudes and practices concerning highway investment appraisal that are taking place in Great Britain has been presented. These stem in part from the deliberations and recommendations of the Leitch Committee, but they are also a reflection of the changing environment in which road planners in most countries now find themselves operating. In Britain the main developments taking place relate to uncertainty (both about future traffic levels and availability of investment funds) and to increasing concern with environmental and other qualitative consequences of highway investment. It is interesting to note that, although responses may differ, the perception of the problems is similar in Europe and the United States.

The potential for wider sharing of experience and cooperative technical work appears considerable and is not limited to the topics discussed here. Two areas stand out. The first concerns questions at the interface of highway engineering and highway economics:

1. The economic picture of the trade-off between pavement quality and vehicle maintenance costs is not as clear as it should be.
2. The relationship between initial construction cost and long-term highway maintenance cost would benefit from further research.

The second is concerned with more strategic matters:

1. How do we ensure that administrative decisions on speed limits, maximum truck weights, and so forth are correctly integrated with investment policy?
2. Is the transport system as a whole consistently appraised; particularly, are road and rail investments being assessed on an equal footing?
3. Are strategic decisions about highway development being subjected to as searching economic scrutiny as the more functional day-to-day decisions on highway design? If not, to what extent is it realistic to try to extend the scope of economic analysis?

All these are questions with significant technical content, which largely transcends national boundaries and administrative conventions. It is hoped that growing international awareness, both within the European Community and across the Atlantic, can make a significant contribution to their solution.

REFERENCES

1. Department of Transport. Report of the Advisory Committee on Trunk Road Assessment. Her Majesty's Stationery Office, London, England, 1978.
2. K.J. Button, A.D. Pearman, and A.S. Fowkes. Car Ownership Modelling and Forecasting. Gower Publishing Co., Ltd, Aldershot, England, 1982.
3. Route Location with Regard to Environmental Issues. Department of the Environment, London, England, 1976.
4. J.C. Tanner. Methods of Forecasting Kilometres per Car. TRRL Report LR968. Transport and Road Research Laboratory, Crowthorne, Berkshire, England, 1981.
5. D.J. Ashley. Uncertainty in the Context of Highway Appraisal. Transportation, Vol. 9, 1981, pp. 249-267.
6. G. Copley. The Quantification of Uncertainties in Traffic Forecasts. In Highway Planning and Design: Proc., Summer Annual Meeting, PTRC Education and Research Services, Ltd., London, England, 1981.

Publication of this paper sponsored by Committee on Application of Economic Analysis to Transportation Problems.

Highway Investment and the National Economy

STEWART E. BUTLER, WALTER E. GAZDA, RICHARD J. HORN,
RENE T. SMITH, HILMY ISMAIL, and ARTHUR L. WEBSTER

ABSTRACT

Analyses conducted by the FHWA have estimated empirical relationships between levels of highway expenditures; the condition of the nation's highways; and highway users' speeds, operating costs, and fuel consumption. In this paper these analyses are extended to explain and quantify the impacts of deterioration of highway performance on (a) the macroeconomic behavior of the U.S. economy and (b) specific industry sectors. The estimated macroeconomic and interindustry impacts are consequences of departures from a base-case, multiyear program of highway expenditures that, by 1995, would restore the physical and operating characteristics of highways to what they were in 1978. Against this base case, this study estimates the consequences of a program of much lower highway expenditures that corresponds closely to FHWA's projections to 1995. The movement from the 1978 service level base case to the low-investment scenario is described in terms of lower highway expenditures and taxes and estimated resultant changes in industrial productivity, motor vehicle depreciation, and highway use. The base case and low-investment scenario are then simulated and compared by a long-term macroeconomic model and by a dynamic input-output model. The macroeconomic impacts are higher prices and lower levels of production, employment, disposable income, consumption, saving, and productivity. Projected impacts on particular industries are diverse. The most adversely affected sectors are for-hire trucking and highway construction firms and their suppliers. Several consumer-oriented industries are also projected to decline because of the weakened state of the overall economy. Several industries closely related to highway use are expected to experience growth in output. These include truck, bus, and trailer bodies; metal stampings; tires; petroleum refining; motor vehicles; and crude petroleum.

Analyses conducted by the FHWA (1) have estimated empirical relationships among levels of highway expenditures; the condition of the nation's highways; and highway users' speeds, operating costs, and fuel consumption. The FHWA Investment/Performance Impact model estimated these relationships for (a) each functional highway class, (b) rural, small urban, and urbanized areas, and (c) four vehicle types. In this paper the FHWA analyses are extended to explain and quantify the impacts of decreases in highway expenditures and highway performance on measures of macroeconomic performance of the U.S. economy. Economic impacts on specific industry sectors are also analyzed. The method of analysis is to compare the levels of economic variables under two specific sets of assumptions about highway conditions. The study makes use of a long-term macroeconomic model and a dynamic input-output model. It is the direction and relative magnitude of the changes, not the estimated absolute levels that are important.

The macroeconomic and interindustry impacts examined in this paper are consequences of departures from a multiyear program of highway expenditures that, by 1995, would restore the operating characteristics of highways to what they were in 1978. As a convenient shorthand, references to this base case will be expressed hereafter in terms of the level of highway performance that existed in 1978. The specific set of changes from the 1978 level of performance, postulated year by year from 1981 to 1995, describes the movement from a 1978 service level that assumes an annual growth in vehicle miles traveled (VMT) of 2.8 percent to a low-investment scenario that corresponds closely to the revenue trend case described in The Status of the Nation's Highways: Conditions and Performance (1, Appendix B). In the low-investment scenario, VMT growth declines as a result of deterioration of highway performance.

Space limitations do not permit a review of previous empirical studies of the implications of highway performance for the national economy. Some of the formidable difficulties that an investigation of this topic entails are discussed in a recent survey paper by the Transportation Research Board (2).

SCENARIO DESCRIPTIONS

In this section the 1978-level base case and the low-investment scenario are described in terms of changes in highway expenditures, taxation, and resultant changes in industrial productivity, motor vehicle depreciation, and highway use.

Highway Expenditures

The capital and noncapital expenditure patterns for the 1978 highway performance scenario and the low-investment scenario are presented in Table 1. The 1978 service level (2.8 percent annual VMT growth) is the base case for analyzing the effects of the low-investment program, which brings about a declining annual growth in VMT because of deteriorating highway performance. The capital expenditures in the base case for the years 1981-1992 are assumed to be sufficient to maintain the 1978 performance level through 1995 if VMT grows annually by 2.8 percent. The pattern of capital expenditures for the low-investment scenario is the one reported in Table A-7 of The Status of the Nation's Highways: Conditions and Performance (1) except that actual and projected capital expenditures for 1981 and 1982 are used in place of the values in the table. The stream of noncapital spending is the same in both scenarios; it too is taken from Table A-7 of the cited report, with appropriate adjustments for 1981 and 1982 values. VMT in the low-investment scenario will continue to increase but by less than 2.8 percent a year.

TABLE 1 Expenditure Scenarios, Capital and Noncapital, 1981-1995[a]

	Constant 1978 Highway Performance (2.8% VMT growth)		Low Investment (declining VMT growth)	
Year	Capital[b]	Noncapital	Capital	Noncapital
1981	17.4	20.7	17.4	20.7
1982	15.7	19.6	15.7	19.6
1983	16.5	23.4	12.7	23.4
1984	19.8	23.5	12.1	23.5
1985	23.0	23.5	11.5	23.5
1986	26.1	23.5	10.8	23.5
1987	29.4	23.3	10.2	23.3
1988	32.7	23.1	9.6	23.1
1989	36.0	22.7	9.1	22.7
1990	39.3	22.4	8.6	22.4
1991	42.7	22.0	8.1	22.0
1992	46.1	21.5	7.7	21.5
1993	45.8	21.0	7.4	21.0
1994	45.4	20.5	7.0	20.5
1995	45.0	19.9	6.6	19.9
Total	480.9	330.6	154.5	330.6

[a]In billions of 1980 dollars.
[b]The capital expenditures for the years 1981-1992, which total $344.7 billion, are assumed to be sufficient to maintain the 1978 performance level through 1995.
Source: Federal Highway Administration and EXP Associates.

Funding Sources

In most years, the low-investment scenario represents a substantial decrease from the level of spending assumed for the 1978 highway performance base case. To obtain comprehensive estimates of the macroeconomic and interindustry implications of these decreases, it is important to account for funding changes. Historically, funding for highways has come from four sources:

1. User fees (including tolls and parking fees),
2. Nonuser taxes,
3. Investment income from highway trust funds, and
4. Bonding.

Information on the relative importance of each of these sources was provided by FHWA, and adjustments in the percentages were made as necessary to accommodate specific characteristics of the two scenarios. In the low-investment scenario, in which highway capital expenditures are cut by more than 50 percent, it is assumed that all spending reductions are matched by reductions in user and nonuser taxes.

The departures from the 1978 base case that have been discussed so far (i.e., changes in highway expenditures and funding) influence highway performance by affecting the kinds and amounts of resources that are devoted to the maintenance and improvement of the nation's roads. Changes in highway performance in turn affect the nation's economy. However, changes in highway spending and funding also influence the economy directly. A reduction in spending on highway construction, for example, will adversely affect output and employment in that industry and in industries that supply materials and services to highway construction firms. Other industries not directly related to highway construction will be negatively affected by multiplier effects. In this paper such fiscal impacts will be distinguished from economic impacts caused by changes in highway performance.

Deterioration of highway performance affects the economy primarily by influencing three variables: productivity, depreciation of motor vehicles, and VMT. In the following sections an explanation is given of how these variables are affected by declines in highway performance, how these effects are measured, and how these effects in turn produce changes in the behavior of key macroeconomic variables.

Productivity

Productivity (i.e., the ratio of outputs to inputs) in virtually every sector of the economy is affected by the performance of the nation's highways because the performance of highways affects the efficiency with which commodities and industry personnel are carried by motor vehicles. Thus, if the low-investment scenario were realized and highways were allowed to deteriorate, transport by motor carriers would be more difficult, slower, and more costly.

The productivity adjustments made to the macroeconomic model for the movement to the low-investment case are presented in Table 2. Reachieving the 1978 highway condition and performance level by 1995 requires increased funding over the historical trend in funding extrapolated into the future (the low-investment case). The productivity values in Table 2 assume that such increases in funding could not be legislated until 1983 and that it would take 3 years of implementation before operational benefits would begin to be realized. Thus there would be no difference in labor productivity between the low-investment and base case until 1986 (values of 1.0 in the table). Using FHWA travel and speed-as-a-function-of-highway-investment forecasts, the 1995 increase in labor productivity that would result from the additional highway expenditures was computed. This 1995 value was 2.3 percent of the base case value. The intermediate 1985 to 1995 values in Table 2 are an exponential interpolation between the 1985 value of 1.0 and the 1995 value [1.0 - (2.3/ 100) = 0.977].

TABLE 2 Adjustments to Productivity and Depreciation in Going from 1978 Service Level to Low-Investment Case

	Adjustment	
Year	Productivity (weighting factor)[a]	Depreciation (billions of 1972 dollars)[b]
1981	1.0	0.0
1982	1.0	0.0
1983	1.0	0.0
1984	1.0	0.0
1985	1.0	0.0
1986	0.998	0.0
1987	0.995	0.8
1988	0.993	1.9
1989	0.991	3.0
1990	0.989	4.5
1991	0.986	6.3
1992	0.984	8.5
1993	0.982	10.8
1994	0.978	13.6
1995	0.977	16.9

[a]Data supplied by EXP Associates.
[b]Data from TSC in association with EXP Associates.

In the analysis of the effects of highway performance on productivity, it was estimated that, during 1978-1980, the number of hours spent in business travel (e.g., by truck drivers and sales persons) exceeded 11 percent of the nation's total wage hours. On the basis of forecasts of VMT, outputs of the FHWA Investment/Performance model, and other published data, labor hours in highway transit were projected for 1995 for each scenario. Differences between the low-investment scenario and the base case were then calculated. Finally, these differences were divided by projections of total U.S. labor hours in 1995 to estimate the percentage changes in overall labor productivity. Clearly, if slower speeds are a consequence of highway deterioration, as the Investment/Performance Impact model indicates, these slower speeds will adversely affect productivity in a large number of industries because more labor and truck hours will be required to accomplish the same amount of motor vehicle carriage.

Depreciation

In the macroeconomic model, the depreciation of trucks and automobiles used for business purposes is a component of a measure of total corporate depreciation. To determine the extent to which this macroeconomic variable should be changed, a series of calculations had to be carried out. First, it was determined that truck bodies, trailer coaches, and motor vehicles and parts purchased by businesses together account for 9 percent of producers' durable equipment. Based on FHWA estimates of changes in operation costs, the rate of depreciation of these vehicles in 1995 was estimated to be 22 percent higher in the low-investment scenario than it would be in the 1978 service level case. For producers' durable equipment, this means a 1995 increase of 1.98 percent in the low-investment scenario.

The dollar equivalents of these percentage changes are given in Table 2. Depreciation effects of the transition to the low-investment scenario are assumed to begin in 1987. Accordingly, the 1.96 percent increase in 1995 was scaled back to zero in 1986.

In the context of the national economy, the impacts of changes in the depreciation of motor vehicles used for transporting goods and for other business purposes can be expected to be smaller than the impacts of changes in productivity discussed previously. Higher depreciation could well result in faster replacement of vehicles and increased expenditures on maintenance, both of which would lead to higher output and employment. Though particular sectors of the economy would thus be stimulated, from a broader economic perspective this outcome is more properly viewed as an opportunity cost, that is, a diversion of resources away from the production of other goods and services.

VMT

For a given level of highway maintenance and capital investment, the level of highway performance is critically affected by the volume of traffic. For example, the faster the growth in VMT, the greater will be the deterioration of highway conditions and performance. At the same time, however, deterioration of highway performance will dampen the growth in traffic because of slower speeds and higher operating costs per mile of travel. This two-way causality was considered an important factor in the determination of the economic impacts of the movement to the low-investment scenario and was incorporated into that analysis by a two-step procedure:

1. A worst-case scenario was developed in which VMT growth would match the 2.8 percent growth of VMT in the 1978 base case, despite the lower speeds and higher operating costs caused by performance deterioration. This was done to take advantage of the Investment/Performance Impact model outputs that were generated on the assumption of a 2.8 percent annual growth in VMT. Under this assumption, operating costs in 1995 were projected to increase almost 28 percent above what they were projected to be in the base case, and average time in transit per VMT was projected to increase 21 percent. Also, the productivity weighting factors in Table 2 were lower than those given, and the increases in depreciation of motor vehicles were larger.
2. The worst-case scenario was modified on the basis of estimates of the effects of highway performance deterioration on VMT. Except for the modifications to productivity and depreciation, which are already incorporated in Table 2, feedback effects

between highway performance and VMT growth were estimated in the context of the input-output model.

Because of the two-way causality, these feedback effects were estimated iteratively. Fortunately, the estimates converged to equilibrium levels after only a few iterations. The result is a simultaneous solution for VMT growth and performance for the low-investment scenario.

THE MACROECONOMIC MODEL

A change in just one of the five variables previously discussed would perturb a complex pattern of economic relationships in ways that would be difficult to analyze and virtually impossible to estimate without the use of an econometric model of the U.S. economy. Analysis and measurement of the macroeconomic impacts of simultaneous changes in all five variables make the use of such a model essential. The macroeconomic model selected for use in this project was developed by Chase Econometrics Associates, Inc.

The Chase Long-Term Macroeconomic Model (3) consists of a set of simultaneous equations developed to predict approximately 700 economic variables. Included in the model are regression equations, identity relations, and assumption-type variables.

Simulation of the base case and the low-investment scenario required that specific variables in the macroeconomic model be modified to reflect the changes previously described. However, because VMT is not a variable in either the Chase Long-Term Macroeconomic Model or the Interindustry Forecasting Model of the University of Maryland (INFORUM), it was necessary to modify variables related to VMT in order to reflect changes in highway use. Two modifications were estimated for the INFORUM model and then aggregated for the macroeconomic model.

The macroeconomic modifications for VMT take the form of higher prices (and thus lower sales) of commodity categories that would be affected by the higher highway transport costs and slower speeds caused by deterioration of highway performance. Thus 1995 prices were increased for the following ten commodity groupings.

Commodity Group	Percent Increase
Recreational vehicles	9.6
Household operations	4.8
Other consumer nondurables	1.2
Tires and parts	1.1
Transportation services	0.8
Food and beverages	0.7
Other consumer services	0.6
Furniture and bedding	0.5
Other consumer durables	0.5
Other household services less rent	0.1

Much smaller price changes were simulated for 1986. These were then increased year by year to the 1995 levels indicated above.

Purchases by consumers of commodities directly affected by deteriorating highway performance were also modified in the macroeconomic model to reflect lower VMT. Sales in 1995 were decreased for four categories as follows:

Commodity	Decrease in Sales (%)
Gasoline and oil	11.0
New passenger car sales	8.4
Tires and parts	2.0
Transportation services	1.9

Like the commodity prices, these decreases in sales were scaled back to the much smaller changes that would be expected to begin in 1986.

After all of the modifications described in this section were effected in the macroeconomic model, the low-investment scenario was simulated by a computer routine that solved for values of all of the dependent variables in the model.

MACROECONOMIC SIMULATION OF THE LOW-INVESTMENT SCENARIO

The total effects of simultaneous changes in highway spending, taxation, productivity, depreciation of motor vehicles, and VMT were estimated for several macroeconomic variables. The effects of a reduction in highway performance from the 1978 service level to the low-investment case on six key variables are presented in Tables 3 through 8. Only columns 3 and 4, which indicate the total macroeconomic impacts, are discussed here. The portion of these impacts that represents purely fiscal effects is shown in columns 5 and 6. The remaining portion, which can be attributed to deterioration of highway performance, is shown in columns 7 and 8.

Four of the macroeconomic variables are measured in 1972 dollars. For making comparisons with the highway expenditure scenarios, which are measured in 1980 dollars, the dollar projections in Tables 3 and 8 should be multiplied by 1.786 (derived from the GNP deflator), and the dollar projections in Tables 5 and 6 by 1.970 (derived from the Consumer Price Index).

Table 3 indicates that GNP is smaller in the low-investment scenario than in the 1978 service level base case (2.8 percent growth in VMT) in every year but 1982. In 1995 the reduction in the output of goods and services is projected to be $72.31 billion, a drop of 3.2 percent. Over the entire simulation period, from 1982 through 1995, the loss is $355.68 billion (in 1972 dollars), more than one-fifth of the 1981 GNP and twice total spending by state and local governments in 1981.

Impacts on prices are presented in Table 4. By 1995 goods and services purchased by consumers will be 8 percent higher than in the base case. The implications of lower output and higher prices are given in Tables 5 and 6. Real disposable income in 1995 is estimated to be lower than in the base case by more than $90 billion, a reduction of 5.9 percent. This is equivalent to an average reduction in real disposable income of $931 per household (based on a projection of 97.3 million households in 1995 by the Bureau of Labor Statistics). Consumer spending in 1995 is estimated to decline below the base-case level by approximately $53 billion, a reduction of $541 or 3.6 percent per household. If average household disposable income and consumer spending are reduced by $931 and $541, respectively, average household saving must be reduced in 1995 by the difference, or $390.

The reduction in GNP brings with it a reduction in employment. Table 7 indicates that by 1995, the number of employed is estimated to be down by 2.66 million workers, a decline of 2.2 percent from employment in the base case. Moreover, this smaller number of employed workers perform at lower levels of productivity. Table 8 gives output per labor hour projected to be lower by 2.7 percent in manufacturing industries.

The overall macroeconomic impacts of deteriorating highway performance thus are estimated to reduce the economic welfare of the nation in terms of higher prices and lower levels of production, em-

TABLE 3 Estimated Impacts on GNP[a] of Change from 1978 Service Level to Low-Investment Case, 1982-1995

	Total Impacts				Impacts of Changes in Expenditures and Taxes		Impacts of Changes in Productivity and Depreciation	
Year	1978 Service GNP	Low-Investment GNP	Impact on GNP	Percent Change	Impact on GNP	Percent of Total Impact	Impact on GNP	Percent of Total Impact
1982	1,510.58	1,513.14	2.56	0.2	2.56	100	0	0
1983	1,574.78	1,572.69	−2.09	−0.1	−2.09	100	0	0
1984	1,639.98	1,636.07	−3.91	−0.2	−3.91	100	0	0
1985	1,698.41	1,693.2	−5.21	−0.3	−5.21	100	0	0
1986	1,747.85	1,740.38	−7.47	−0.4	−6.53	87.4	−0.94	12.6
1987	1,803.00	1,792.46	−10.54	−0.6	−7.53	71.4	−3.01	28.6
1988	1,857.45	1,842.93	−14.52	−0.8	−8.37	57.6	−6.15	42.4
1989	1,912.57	1,892.2	−20.37	−1.1	−9.06	44.5	−11.31	55.5
1990	1,968.48	1,940.44	−28.04	−1.4	−9.51	33.9	−18.53	66.1
1991	2,021.43	1,985.58	−35.85	−1.8	−9.98	27.8	−25.87	72.2
1992	2,078.65	2,034.28	−44.37	−2.1	−10.03	22.6	−34.34	77.4
1993	2,135.25	2,083.14	−52.11	−2.4	−7.94	15.2	−44.17	84.8
1994	2,191.57	2,130.12	−61.45	−2.8	−6.28	10.2	−55.17	89.8
1995	2,249.04	2,176.73	−72.31	−3.2	−4.99	6.9	−67.32	93.1

[a]In billions of 1972 dollars.

TABLE 4 Estimated Impacts on Consumer Price Index[a] of Change from 1978 Service Level to Low-Investment Case, 1982-1995

	Total Impacts				Impacts of Changes in Expenditures and Taxes		Impacts of Changes in Productivity and Depreciation	
Year	1978 Service CPI	Low-Investment CPI	Impact on CPI	Percent Change	Impact on CPI	Percent of Total Impact	Impact on CPI	Percent of Total Impact
1982	293.75	293.89	0.14	0	0.14	100	0	0
1983	317.15	317.12	−0.03	0	−0.03	100	0	0
1984	341.36	341.5	0.14	0	0.14	100	0	0
1985	366.71	366.82	0.11	0	0.11	100	0	0
1986	391.68	392.54	0.86	0.2	−0.08	7.8	0.94	92.2
1987	418.64	421.04	2.4	0.6	−0.39	12.3	2.79	87.7
1988	446.42	451.26	4.84	1.1	−0.8	12.4	5.64	87.6
1989	473.98	482.19	8.21	1.7	−1.35	12.4	9.56	87.6
1990	503.49	516.14	12.65	2.5	−2.03	12.1	14.68	87.9
1991	533.35	551.35	18.0	3.4	−3.03	12.6	21.03	87.4
1992	565.79	590.52	24.73	4.4	−4.21	12.7	28.94	87.3
1993	598.88	631.85	32.97	5.5	−5.39	12.3	38.36	87.7
1994	634.2	676.86	42.66	6.7	−7.01	12.4	49.67	87.6
1995	671.48	725.18	53.7	8.0	−9.0	12.6	62.7	87.4

[a]1967 = 100.

TABLE 5 Estimated Impacts on Disposable Personal Income[a] of Change from 1978 Service Level to Low-Investment Case

	Total Impacts				Impacts of Changes in Expenditures and Taxes		Impacts of Changes in Productivity and Depreciation	
Year	1978 Service Income	Low-Investment Income	Impact on Income	Percent Change	Impact on Income	Percent of Total Impact	Impact on Income	Percent of Total Impact
1982	1,062.91	1,063.38	0.47	0	0.47	100	0	0
1983	1,109.12	1,108.95	−0.17	0	−0.17	100	0	0
1984	1,140.75	1,141.12	0.37	0	0.37	100	0	0
1985	1,171.21	1,172.36	1.15	0.1	1.15	100	0	0
1986	1,202.9	1,203.71	0.81	0.1	1.94	63.2	−1.13	36.8
1987	1,237.01	1,236.04	−0.97	−0.1	2.99	43.0	−3.96	57.0
1988	1,271.51	1,267.17	−4.34	−0.3	4.29	33.2	−8.63	66.8
1989	1,308.11	1,297.37	−10.74	−0.8	5.7	25.7	−16.44	74.3
1990	1,340.1	1,320.25	−19.85	−1.5	7.35	21.3	−27.2	78.7
1991	1,376.88	1,348.3	−28.58	−2.1	8.95	19.3	−37.53	80.7
1992	1,411.16	1,370.78	−40.38	−2.9	10.95	17.6	−51.33	82.4
1993	1,446.93	1,392.58	−54.35	−3.8	12.9	16.1	−67.25	83.9
1994	1,483.71	1,412.59	−71.12	−4.8	14.21	14.3	−85.33	85.7
1995	1,523.61	1,433.05	−90.56	−5.9	15.7	12.9	−106.26	87.1

[a]In billions of 1972 dollars.

TABLE 6 Estimated Impacts on Consumption[a] of Change from 1978 Service Level to Low-Investment Case, 1982-1995

	Total Impacts				Impacts of Changes in Expenditures and Taxes		Impacts of Changes in Productivity and Depreciation	
Year	1978 Service Consumption	Low-Investment Consumption	Impact on Consumption	Percent Change	Impact on Consumption	Percent of Total Impact	Impact on Consumption	Percent of Total Impact
1982	975.18	975.77	0.59	0.1	0.59	100	0	0
1983	1,015.95	1,015.78	−0.17	0	−0.17	100	0	0
1984	1,056.59	1,056.56	−0.03	0	−0.03	100	0	0
1985	1,089.98	1,090.3	0.32	0	0.32	100	0	0
1986	1,122.37	1,122.17	−0.2	0	0.59	42.8	−0.79	57.2
1987	1,156.87	1,155.6	−1.27	−0.1	1.0	30.6	−2.27	69.4
1988	1,191.38	1,188.27	−3.11	−0.3	1.52	24.7	−4.63	75.3
1989	1,227.68	1,220.9	−6.78	−0.6	2.09	19.1	−8.87	80.9
1990	1,264.7	1,252.54	−12.16	−1.0	2.75	15.6	−14.91	84.4
1991	1,300.17	1,282.45	−17.72	−1.4	3.33	13.7	−21.05	86.3
1992	1,336.46	1,312.07	−24.39	−1.8	4.18	12.8	−28.57	87.2
1993	1,371.97	1,339.66	−32.31	−2.4	5.08	12.0	−37.39	88.0
1994	1,407.34	1,365.44	−41.9	−3.0	5.59	10.5	−47.49	89.5
1995	1,443.75	1,391.08	−52.67	−3.6	6.06	9.4	−58.73	90.6

[a]In billions of 1972 dollars.

TABLE 7 Estimated Impacts on Number of Employed[a] of Change from 1978 Service Level to Low-Investment Case, 1982-1995

	Total Impacts				Impacts of Changes in Expenditures and Taxes		Impacts of Changes in Productivity and Depreciation	
Year	1978 Service Employed	Low-Investment Employed	Impact on Employed	Percent Change	Impact on Employed	Percent of Total Impact	Impact on Employed	Percent of Total Impact
1982	92.11	92.33	0.22	0.2	0.22	100	0	0
1983	95.41	95.37	−0.04	0	−0.04	100	0	0
1984	97.97	97.83	−0.14	−0.1	−0.14	100	0	0
1985	100.24	100.02	−0.22	−0.2	−0.22	100	0	0
1986	102.00	101.68	−0.32	−0.3	−0.33	97.1	0.01	2.9
1987	104.13	103.71	−0.42	−0.4	−0.42	100	0	0
1988	106.24	105.7	−0.54	−0.5	−0.48	88.9	−0.06	11.1
1989	108.33	107.6	−0.73	−0.7	−0.53	72.6	−0.2	27.4
1990	110.49	109.48	−1.01	−0.9	−0.59	58.4	−0.42	41.6
1991	111.93	110.6	−1.33	−1.2	−0.68	51.1	−0.65	48.9
1992	113.68	112.02	−1.66	−1.5	−0.74	44.6	−0.92	55.4
1993	115.32	113.4	−1.92	−1.7	−0.67	34.9	−1.25	65.1
1994	117.04	114.83	−2.21	−1.9	−0.64	29.0	−1.57	71.0
1995	118.68	116.02	−2.66	−2.2	−0.63	23.7	−2.03	76.3

[a]In millions.

TABLE 8 Estimated Impacts on Labor Productivity in Manufacturing[a] of Change from 1978 Service Level to Low-Investment Case, 1982-1995

	Total Impacts				Impacts of Changes in Expenditures and Taxes		Impacts of Changes in Productivity and Depreciation	
Year	1978 Service Productivity	Low-Investment Productivity	Impact on Productivity	Percent Change	Impact on Productivity	Percent of Total Impact	Impact on Productivity	Percent of Total Impact
1982	9.08	9.07	−0.01	−0.1	−0.01	100	0	0
1983	9.33	9.3	−0.03	−0.3	−0.03	100	0	0
1984	9.64	9.62	−0.02	−0.2	−0.02	100	0	0
1985	10.07	10.05	−0.02	−0.2	−0.02	100	0	0
1986	10.42	10.4	−0.02	−0.2	0.0	0	−0.02	100
1987	10.74	10.68	−0.06	−0.6	0.01	12.5	−0.07	87.5
1988	11.09	11.01	−0.08	−0.7	0.01	10.0	−0.09	90.0
1989	11.46	11.34	−0.12	−1.0	0.01	7.1	−0.13	92.9
1990	11.84	11.68	−0.16	−1.4	0.01	5.6	−0.17	94.4
1991	12.28	12.1	−0.18	−1.5	0.05	17.9	−0.23	82.1
1992	12.77	12.54	−0.23	−1.8	0.05	15.2	−0.28	84.8
1993	13.22	12.95	−0.27	−2.0	0.06	15.4	−0.33	84.6
1994	13.64	13.29	−0.35	−2.6	0.06	12.8	−0.41	87.2
1995	14.06	13.68	−0.38	−2.7	0.07	13.5	−0.45	86.5

[a]Output per labor hour in 1972 dollars.

ployment, disposable income, consumption, savings, and productivity.

THE INPUT-OUTPUT MODEL

In this section, the focus of the analysis of the deterioration of highway performance shifts from macroeconomic impacts to consequences for particular industry sectors. The Chase Econometrics version of INFORUM was used to analyze these consequences.

The model used to assess the impacts of departures from the 1978 service level on particular sectors of the economy is a version of INFORUM developed by Chase Econometrics Associates (4). The Chase version of INFORUM is a 200-industry dynamic input-output model that is linked to the Chase Long-Term Macroeconomic Model. This linkage provides compatibility and consistency between the macroeconomic and industry-specific analyses.

The input-output matrices of INFORUM were modified extensively to incorporate FHWA projections of the costs of highway use in 1995 in the 1978 service level base case and in the low-investment scenario. The procedure for effecting these modifications is a series of complex and highly detailed calculations. Such an involved procedure is needed because only about one-half of total highway user costs are explicit in the matrices. The others are imbedded in the values of matrix cells.

Modification of the 1978 base case requires only that the column for highway construction in the construction sector matrix match the expenditures that were projected for this case by FHWA. The low-investment scenario requires many additional changes because only two of the 200 INFORUM sectors portray highway transportation explicitly: trucking and warehousing, and local and interurban transit. But even these inadequately reflect the condition and performance of highways alone, because the first includes warehousing and the second includes rail transit. Moreover, these two INFORUM sectors account for only a small fraction of the nation's highway travel costs.

Fortunately, an earlier study (5) estimates some relationships between highway transportation and sectors of INFORUM. Columns were developed for 13 categories of highway transportation:

1. For-hire intercity truck,
2. For-hire local truck,
3. Transit,
4. Taxi,
5. Intercity bus,
6. Private intercity freight truck,
7. Private local freight truck,
8. Private nonfreight truck,
9. Government truck,
10. Business automobile,
11. Personal automobile,
12. School bus, and
13. Other bus.

These categories account for nearly all expenditures for highway transportation.

The outputs of the FHWA Investment/Performance Impact Analysis models and FHWA's forecasts of VMT were used to estimate 1995 highway operating costs for automobiles and three truck classes for urban areas and for rural areas. Because FHWA assumed VMT growth to be 2.8 percent a year in the low-investment scenario, the initial low-investment estimates represent a worst-case scenario. This scenario was subsequently modified to reflect the negative effects of deterioration of highway performance on VMT growth. These estimates, calculated for the 1978 base case and the low-investment scenario, were translated into changes in the 13 columns named previously, after the columns were updated on the basis of recent highway revenue and expenditure data. These modified versions of INFORUM, representing the 1978 service level and the low-investment scenario, were matched with and driven by corresponding macroeconomic scenarios. Space limitations do not permit discussion of the six-step procedure that was followed to modify INFORUM. However, the steps are presented in detail in Highways and the Economy (6).

INPUT-OUTPUT SIMULATION OF THE LOW-INVESTMENT SCENARIO

The results of simulating the interindustry structure of the U.S. economy under the low-investment scenario are presented in this section along with a comparison of this simulation with its 1978 service-level base of departure. The INFORUM simulation results are measured in 1977 dollars. For making comparisons with the highway expenditure scenarios, which are measured in 1980 dollars, the dollar projections in Tables 9 through 12 should be multiplied by 1.276. Tables 9 and 10 present estimated differences in 1995 output and consumer purchases for selected industries that would be directly affected by a movement from the 1978 service level case to the low-investment scenario. The first four sectors in Table 9 are projected to incur substantial reductions in output as a consequence of lower levels of capital spending on highways and lower levels of activity in the economy generally.

The next eight sectors are directly affected by deterioration of highway performance and reductions in VMT attributable to this deterioration. The metal stampings sector is included, because it is an important supplier to the motor vehicle industry and to producers of truck, bus, and trailer bodies. The crude petroleum sector is included because of its sales to petroleum refining firms.

The increases in output of the first six of these eight sectors, though a boon to these industries, represent a social cost, because such increases divert resources away from other sectors of the economy. This diversion of resources occurs despite lower consumer purchases, which are given in Table 10. Lower consumer purchases are the direct result of reductions in VMT. Lower purchases imply that the increased outputs of these six sectors are the result of the impacts of performance deterioration on private and for-hire trucking. This waste of resources would be even greater in the absence of lower levels of macroeconomic activity, which represent social burdens of a different kind, that is, the unemployment of capital and labor.

The outputs and consumer purchases of the last two sectors in this group of eight, batteries and auto repair, are both lower than in the 1978 service level case. These reductions can be attributed to the sensitivity of VMT to increased costs of highway use and to the general decrease in the level of economic activity.

The last four lines in Table 9 indicate modal impacts of deterioration of highway performance. The easiest mode to understand is for-hire trucking, whose 1995 output is estimated to be 18 percent lower than in the 1978 service level case. First, many commodities become more expensive in the low-investment scenario. This leads to reduced sales and shipments. Second, the price of for-hire trucking increases. Finally, for-hire trucking can be expected to suffer from declines in macroeconomic activity.

TABLE 9 Industrial Sectors Significantly Affected by Movement from 1978 Service Level Case to Low-Investment Scenario: Estimated Changes in 1995 Output[a]

Sector	1978 Service Level	Low-Investment	Change	Percent Change
Related to Highway Expenditures				
Paving and asphalt	8,430.6	5,184.8	−3,245.8	−38.5
Cement, concrete, gypsum	26,732.5	19,675.1	−7,057.4	−26.4
Stone and clay mining	11,318.1	8,511.2	−2,806.9	−24.8
Other structural metal products	38,876.0	32,072.7	−6,803.3	−17.5
Related to Highway Use				
Truck, bus, trailer bodies	12,843.7	14,770.2	1,926.5	15.0
Metal stampings	22,881.7	26,108.0	3,226.3	14.1
Tires and inner tubes	16,259.9	17,560.7	1,300.8	8.0
Petroleum refining	123,131.0	128,918.0	5,787.2	4.7
Motor vehicles	191,055.0	196,978.0	5,922.7	3.1
Crude petroleum	29,302.7	29,419.9	117.2	0.4
Batteries	6,824.6	6,688.1	−136.5	−2.0
Automobile repair	80,266.0	70,874.9	−9,391.1	−11.7
Related to Other Modes				
Buses and local transit	12,224.0	13,605.3	1,381.3	11.3
Railroads	38,962.1	42,507.7	3,545.6	9.1
Airlines	51,757.8	45,495.1	−6,262.7	−12.1
Trucking	104,686.0	85,633.0	−19,052.8	−18.2

[a]In millions of 1977 dollars.

TABLE 10 Industrial Sectors Significantly Affected by Movement from 1978 Service Level Case to Low-Investment Scenario: Estimated Changes in 1995 Consumer Purchases[a]

Sector	1978 Service Level	Low-Investment	Change	Percent Change
Related to Highway Expenditures				
Cement, concrete, gypsum	4.5	3.7	−0.8	−18.3
Stone and clay mining	73.7	65.7	−8.0	−10.8
Other structural metal products	298.8	270.7	−28.1	−9.4
Related to Highway Use				
Metal stampings	1,055.7	1,013.5	−42.2	−4.0
Tires and inner tubes	17,997.9	17,152.0	−845.9	−4.7
Petroleum refining	39,616.9	35,259.0	−4,357.9	−11.0
Motor vehicles	81,522.8	74,674.9	−6,847.9	−8.4
Batteries	7,083.9	7,006.0	−77.9	−1.1
Automobile repair	40,700.7	38,625.0	−2,075.7	−5.1
Related to Other Modes				
Buses and local transit	6,798.5	7,050.0	251.5	3.7
Railroads	394.0	453.1	59.1	15.0
Airlines	20,372.6	19,191.0	−1,181.6	−5.8
Trucking	4,776.5	4,079.1	−697.4	−14.6

[a]In millions of 1977 dollars.

TABLE 11 Consumer Goods Sectors Significantly Affected by Movement from 1978 Service Level Case to Low-Investment Scenario: Estimated Changes in 1995 Output[a]

Sector	1978 Service Level	Low-Investment	Change	Percent Change
Telephone and telegraph	125,626.0	88,943.4	−36,682.9	−29.2
Drugs	19,584.9	16,040.0	−3,544.9	−18.1
Watches and clocks	2,848.5	2,407.0	−441.5	−15.5
Books	11,371.4	9,927.2	−1,444.2	−12.7
Fruits, vegetables, other crops	45,079.0	39,714.6	−5,364.4	−11.9
Poultry and eggs	11,430.8	10,242.0	−1,188.8	−10.4
Hotel and lodging places	23,727.5	21,425.9	−2,301.6	−9.7
Photographic equipment	27,039.0	24,524.4	−2,514.6	−9.3
Medical services	177,740.0	162,454.0	−15,285.6	−8.6
Canned and frozen foods	33,061.7	30,482.9	−2,578.8	−7.8
Apparel	53,988.1	50,640.8	−3,347.3	−6.2
Soft drinks and flavorings	16,233.8	15,259.8	−974.0	−6.0
Meat products	60,296.4	57,462.5	−2,833.9	−4.7
Phonograph records	2,817.8	2,707.9	−109.9	−3.9
Household furniture	18,524.6	17,839.2	−685.4	−3.7
Newspapers	20,951.9	20,281.4	−670.5	−3.2
Household appliances	21,286.5	20,796.9	−489.6	−2.3
Eating and drinking places	129,954.0	127,875.0	−2,079.3	−1.6
Alcoholic beverages	25,354.2	24,999.2	−355.0	−1.4

[a]In millions of 1977 dollars.

TABLE 12 Consumer Goods Sectors Significantly Affected by Movement from 1978 Service Level Case to Low-Investment Scenario: Estimated Changes in 1995 Consumer Purchases[a]

Sector	1978 Service Level	Low-Investment	Change	Percent Change
Telephone and telegraph	43,299.4	36,934.4	−6,365.0	−14.7
Drugs	13,799.0	12,695.1	−1,103.9	−8.0
Watches and clocks	3,014.1	2,676.5	−337.6	−11.2
Books	7,353.9	7,015.6	−338.3	−4.6
Fruits, vegetables, other crops	20,371.0	19,413.6	−957.4	−4.7
Poultry and eggs	3,905.6	3,827.5	−78.1	−2.0
Hotel and lodging places	11,877.8	11,260.2	−617.6	−5.2
Photographic equipment	5,654.4	5,196.4	−458.0	−8.1
Medical services	155,809.0	145,058.0	−10,750.8	−6.9
Canned and frozen foods	32,070.4	30,210.3	−1,860.1	−5.8
Apparel	81,003.9	78,330.8	−2,673.1	−3.3
Soft drinks and flavorings	14,125.3	13,404.9	−720.4	−5.1
Meat products	45,472.8	43,926.7	−1,546.1	−3.4
Phonograph records	4,963.0	4,794.3	−168.7	−3.4
Household furniture	26,428.3	24,499.0	−1,929.3	−7.3
Newspapers	6,907.5	6,603.6	−303.9	−4.4
Household appliances	26,033.9	25,539.3	−494.6	−1.9
Eating and drinking places	99,684.2	95,198.4	−4,485.8	−4.5
Alcoholic beverages	35,177.2	34,755.1	−422.1	−1.2

[a]In millions of 1977 dollars.

The increase in rail output is consistent with the higher costs of both private and for-hire trucking, which are substitute modes. Similarly, the increased output of bus and local transit can be explained by reductions in personal VMT, which are apparently large enough to offset the negative effects of an increase in the price of bus and local transit. The decrease in airline output could be anticipated because of the projected state of the economy in the low-investment scenario.

Tables 11 and 12 present estimated impacts on selected consumer goods industries less directly related to highway expenditures, highway use, or specific transportation modes. The more important explanatory variables for the results given in Tables 11 and 12 would appear to be aggregate disposable income and consumer spending, which, as Tables 5 and 6 indicate, decrease by 5.9 percent and 3.6 percent respectively because of the decline in the overall economy. That these macroeconomic impacts would affect some sectors more than others is evident from the variability indicated in Tables 11 and 12.

It is thus clear that although the output and sales of a few major industries would increase as a consequence of the deterioration of highway performance, most sectors of the economy would suffer declines. Industries that would experience the largest losses include for-hire trucking and highway construction firms and their suppliers.

SUMMARY

If the low-investment scenario were allowed to run its course, projected impacts on the macroeconomic performance of the economy in 1995 would include the following changes from the 1978 service level base case.

Macroeconomic Variable	Percentage Change
Gross National Product	-3.2
Consumer Price Index	+8.0
Disposable income	-5.9
Consumption expenditures	-3.6
Employment	-2.2
Labor productivity in manufacturing	-2.7

The overall macroeconomic impacts of deteriorating highway performance thus are to reduce the economic welfare of the nation in terms of higher prices and lower levels of production, employment, disposable income, consumption, and productivity.

Impacts of performance deterioration on output levels of particular industries are quite diverse. The most adversely affected sectors are for-hire trucking (-18.2 percent) and highway construction firms and their suppliers (paving and asphalt, -38.5 percent; cement, concrete, and gypsum, -26.4 percent; stone and clay mining, -24.8 percent; and other structural metal products, -17.5 percent). The automobile repair industry is projected to incur a decline of 11.7 percent as a result of the associated decrease in the growth of VMT, and the output of the airlines is estimated to fall by 12.1 percent because of lower GNP, employment, and disposable income. Several additional consumer-oriented industries could also be expected to decline because of the weakened state of the economy.

Several industries that are projected to experience growth in output are those closely related to highway use. These include truck, bus, and trailer bodies (15.0 percent), metal stampings (14.1 percent), tires and inner tubes (8.0 percent), petroleum refining (4.7 percent), motor vehicles (3.1 percent), and crude petroleum (0.4 percent). From a societal point of view, these increases in output are a burden because they represent a diversion of resources away from other sectors of the economy.

The effects felt by households are a function of household income. Under both the low-investment and the 1978 service level scenarios, average family income is forecast to grow in real terms, from $17,400 in 1982 to $21,300 in 1995 under the low-investment assumptions and to $22,700 under the 1978 service level assumptions (income and expenditure figures in 1977 constant dollars). These are equivalent to growth rates of 1.6 percent and 2.1 percent per year.

If the low-investment results were realized, households would accommodate the lower level of income by both spending and saving less. Overall, personal consumption expenditures in 1995 would be expected to be nearly $800 lower, a reduction of 3.6 percent. The input-output results indicate how this $800 is allocated across purchase groups. Significant changes are shown in the following table.

Purchase Class	Expenditure Reduction ($)
Food	76
Household furnishings	49
Clothing	36
Medical care	122
Transportation	164
Entertainment	61
Services	54

Of course these changes are relative. If compared to 1982 expenditure levels, all classes would show a positive growth.

The lower level of expenditure for transportation reflects the reduced mobility of households under the low-investment case. In the 1978 service level scenario, the typical U.S. family is projected to drive 17,226 miles in 1995. In the low-investment scenario, that family's highway VMT would be 12,786 miles, a reduction of 26 percent, or 4,440 miles. This would lead to less frequent replacement of motor vehicles and smaller expenditures on items related to automobile use. For example, the family would spend $45 less on gasoline, $21 less on automobile repairs, and $9 less on tires. On the other hand, there would be a minor increase in the use of buses, local transit, and railroads.

ACKNOWLEDGMENTS

Research for this paper was sponsored by the Office of Program and Policy Planning in the FHWA, U.S. Department of Transportation. The authors gratefully acknowledge advice and support from Harry B. Caldwell, program sponsor; William F. Reulein, Chief of the Policy Development Branch; Madeleine S. Bloom, Chief of the Policy Planning and Coordination Division; and William L. Mertz, Director of the Office of Program and Policy Planning.

REFERENCES

1. The Status of the Nation's Highways: Conditions and Performance. Report of the Secretary of Transportation to the United States Congress. U.S. Government Printing Office, Washington, D.C., Jan. 1981.
2. A Survey of Techniques Used to Assess the Influence of Transportation on Economic Growth. DOT DTOS-59-81-C-00086. TRB, National Research Council, Washington, D.C., April 1982.
3. The Chase Macroeconomic Model. Chase Econometrics, Bala Cynwyd, Pa., n.d.
4. INFORUM. Chase Econometrics, Bala Cynwyd, Pa., n.d.
5. Jack Faucett Associates, Inc. The Department of Transportation Long-Range Forecast Model. Report DOT-OST-P10-80-1. U.S. Department of Transportation, Washington, D.C., Jan. 1980.
6. Highways and the Economy. FHWA-PL-83-014. U.S. Department of Transportation, Nov. 1983.

Publication of this paper sponsored by Committee on Application of Economic Analysis to Transportation Problems.

Casino Bus Transportation System

WALTER CHERWONY

ABSTRACT

The relationship between transportation services and economic development has been well established. An interesting case study of this link is the casino bus transportation system serving Atlantic City, New Jersey. The casino buses provide a premium intercity bus service connecting numerous metropolitan areas in the Northeast Corridor with nine casinos. The casino buses bring more than ten million visitors to this resort community annually and in large measure have contributed to the economic success of legalized casino gambling. In this paper a description is presented of how the service is provided including the various subsidies and incentives provided by the casinos. Bus and passenger volumes, which indicate the dimensions of this privately operated bus service, are also presented. There is a discussion of the economic benefits of the special bus service as well as of the necessary role of government.

The need for transportation services and facilities to support economic development has been well established. Moreover, the location and pattern of industrial and commercial development within a region or state have often been influenced by existing or proposed transportation facilities. In some cases other factors such as business climate and labor force characteristics have guided development decisions. However, these situations typically call for the planning and implementation of transportation services to support development. An interesting case study of the latter situation is the casino bus operations in Atlantic City, New Jersey.

Several years ago Atlantic City became the first area outside Nevada to have legalized casino gambling. The introduction of this significant tourist attraction has reversed the decline in visitors to this resort community. At present nine hotels and casinos are in operation, and another is under construction. Several more hotels and casinos are planned as is expansion of existing casinos. Casino gambling has resulted in substantial construction, the creation of tens of thousands of new jobs, and the rapid expansion of Atlantic City's economic base.

As a result of this development a new transportation system (casino bus), which provides an incentive for tourists to visit the hotels and casinos and thereby encourages further economic development, evolved. Also, because it relies on intercity coaches, the casino bus transportation system is an environmentally attractive and energy efficient transport mode. This use of common carrier vehicles is desirable from a traffic engineering viewpoint because of the narrow grid network of streets in Atlantic City.

The casino buses represent an interesting case study for a variety of reasons. First, the Atlantic City example clearly indicates the linkage and interrelationship between transportation and economic development. Second, the magnitude of the system and the number of passengers carried are larger than those of most urban bus systems. Third, the casino bus system is owned and operated by private carriers and has evolved over the past few years with no previous planning efforts. Fourth, the bus system is an integral part of each casino's marketing program and provides incentives to attract patrons. Finally, the casino bus system has necessitated an unusual role and level of responsibility for transportation agencies in the Atlantic City area.

From the foregoing discussion it would appear that the Atlantic City casino bus system provides an usual case study of transportation and economic development. A description of the system from the perspective of the passengers, operators, and casinos is presented in this paper. Also presented are the economic impact of the bus system and the promotional activities to encourage visitors and tourist expenditures that translate into jobs. Finally, as brief discussion is provided of the function and role of government in regard to a privately owned and operated casino bus system.

SYSTEM DESCRIPTION

The use of buses to transport visitors to Atlantic City is not surprising in view of the strategic location of this resort community within the Northeast Corridor. Several large urban areas (e.g., New York, Philadelphia, and Baltimore) are within a relatively short driving distance of Atlantic City. Given the generally unsuitable nature of air travel and the current deteriorated state of rail service to and from the area, the bus service represents a mode that is competitive with the private automobile. Before casino gambling, conventional intercity bus service was offered between Atlantic City and other metropolitan areas. Patrons were transported from a terminal in their home town to the Municipal Bus Terminal in Atlantic City. In some cases riders had to transfer at intermediate locations to complete a trip when direct bus service was not provided. This type of bus service continues today although its relative importance has been somewhat less since the introduction of casino buses.

The casino bus transportation system affords a premium service at reduced fares, and riders are provided cash premiums and other incentives. The service is operated by private carriers with the approval of the individual casinos. Routes typically originate at shopping centers in residential areas where patrons can park their cars and purchase tickets. This affords riders a relatively convenient trip because they do not have to travel to a downtown bus terminal as is the case with conventional intercity bus service. Further, casino buses originate at numerous locations throughout the metropolitan areas thereby enhancing coverage. Typically, buses stop at a few locations to pick up passengers and then travel nonstop to a particular casino. Approximately 6 hours later the bus returns to the casino to pick up passengers and then travels to the originating locations.

At the casino, before unloading, riders are issued coupons that can be redeemed at the casino for cash and other premiums. Most casinos offer riders at least $10 in quarters as well as meal slips and other promotional incentives. The cash value of the premiums varies among the nine casinos and reflects the competitive nature of the gambling industry and its marketing efforts to attract visitors. Because the cash incentive nearly equals the bus fare, the casinos are providing a user-side subsidy to riders. With the exception of shared advertising expenses, the casinos make no direct payments to the bus companies. Another feature of the casino bus system, with respect to user costs, is the discounting of fares. In most urban areas casino bus fares are less than those charged on intercity buses. In general, the greater the distance from Atlantic City, the greater the fare discount.

Two primary types of casino bus service are provided by the private operators--line and charter. Line runs are similar to scheduled line-haul intercity bus service. Buses operate along a fixed route with a predetermined schedule. Unlike conventional intercity service, casino bus patrons must make an advance reservation (a day or two before the trip). When the number of passengers exceeds the capacity of the scheduled buses, additional buses or extra sections may be added. As previously noted, most casino buses travel to and from only one casino. When there is less than a fully seated load to a single casino, casino buses are sometimes scheduled to stop at two or three casinos. This situation reflects the need for each operator to recover costs and a reasonable profit from farebox revenue.

Charter service is used when a group makes arrangements with either a bus operator or a casino. Patrons are offered relatively low fares, cash and other incentives from the casinos, and are provided with a 6-hour visit. Reservations are normally made 2 to 3 months in advance and confirmed several weeks before the trip.

Casino buses are operated by several dozen carriers although approximately ten operators serving the Philadelphia and New York metropolitan areas account for the majority of buses and patrons. Each casino has a bus program that is an integral part of its overall marketing plan. The casinos control the number of arriving buses because the carriers must have prior authorization to stop at a casino. Operators can be prohibited from discharging passengers at a casino. More important, casinos can refuse to issue coupons, redeemable for cash or meals, or other incentives to passengers. Of particular note is that all services and facilities of the casino bus system are provided by private firms.

BUS AND PATRONAGE VOLUMES

The quarterly growth in the casino bus transportation system and the importance of this transport mode are clearly underscored by the bus volume trend shown in Figure 1. As each new casino has opened, it has instituted a casino bus program in cooperation with private carriers. Of interest is the steady increase in bus volumes during the 3-year period when the number of casinos increased from one to nine. These results would suggest that the casino bus market increases with each new casino. Further, the increase in bus volumes is large enough that increases in the number of buses to each new casino are attained by overall market growth rather than by diversion from other casinos. Another interesting observation is that the rate of growth is not declining. This would suggest that a saturation level of bus volumes should not occur in the foreseeable future, especially given the construction of new casinos. The casino bus transportation system can be expected to grow at the same rate as casino development.

To further describe the dimensions of the casino bus system, bus activity level data from July 1982 for the casinos are summarized in Table 1. Bus volumes vary considerably by day of the week. The largest bus volumes are observed on Wednesday and are nearly one-sixth greater than those of the average day. Tuesdays and Thursdays also have relatively high bus volumes, which would indicate that peak travel days occur during the middle of the week. In contrast, bus volumes preceding (Friday) and following (Monday) the weekend are relatively low. During the weekend bus volumes are generally smaller than during weekdays, and there is considerable variation between Saturday and Sunday. The daily variation in bus volumes is attributable to two major factors. First, bus volumes reflect the days on which tourists wish to visit Atlantic City. Second, the casinos attempt to attract casino bus patrons when other visitor activity levels are relatively low. For example, the casinos sometimes increase the premiums during slow days such as weekdays, and during busy periods (e.g., weekends) the incentives are often reduced. Because the bus program is an integral part of each casino's marketing program, desired activity levels are important in establishing bus activity levels.

Regardless of the day examined, the bus volumes are substantial. The dimensions of the system are apparent from comparisons with other bus systems. For example, New Jersey Transit, which provides public transportation throughout the entire state, operates approximately 1,200 buses during the morning and evening rush hours. Moreover, few transit systems in the nation operate as many buses as are in service in the casino bus system.

Another way to describe the casino bus transportation system is by the type of service offered. About five of every six casino buses are line runs (see Table 2). The proportion of charter buses fluctuates by day of the week with the greatest number and percentage of all buses noted on Sunday. The proportion of other buses declines between Monday and Friday. Like the daily variation in bus volumes, the number

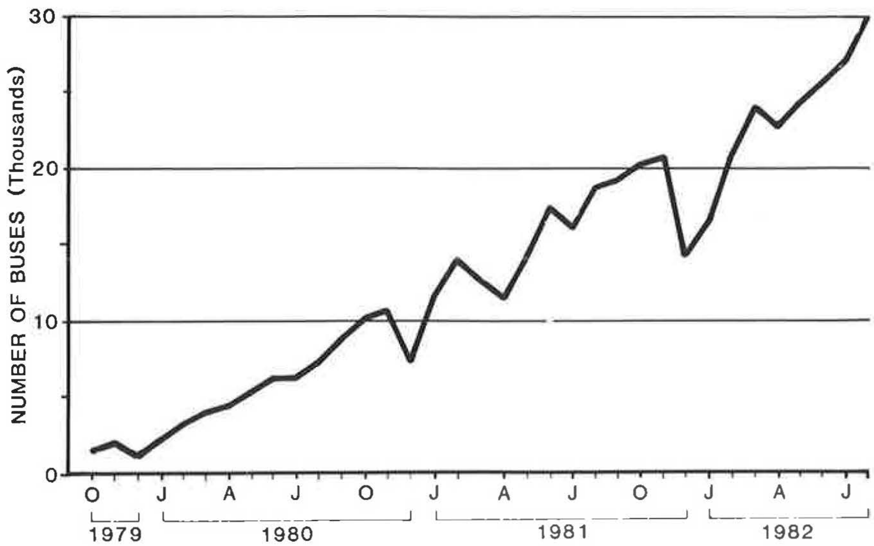


FIGURE 1 Trend in bus volume activity.

TABLE 1 Daily Variation in Bus Volumes—Summer 1982

Day	Number of Buses	Percentage of Daily Average
Weekend		
Saturday	940	97
Sunday	785	81
Average	864	89
Weekday		
Monday	902	93
Tuesday	1,057	109
Wednesday	1,111	115
Thursday	1,039	107
Friday	947	98
Average	1,012	105
Daily average	967	100

TABLE 2 Bus Volumes by Service Type—Summer 1982

Day	Number of Buses			Percent Charter
	Line	Charter	Total	
Weekend				
Saturday	805	135	940	14.4
Sunday	672	163	785	20.8
Average	713	151	864	17.5
Weekday				
Monday	733	169	902	18.7
Tuesday	883	174	1,057	16.5
Wednesday	931	180	1,111	16.2
Thursday	896	143	1,039	13.8
Friday	835	112	947	11.8
Average	856	156	1,012	15.4
Daily average	813	154	967	15.9

of buses by service type reflects the marketing strategy of each casino. It should be recognized that some casinos prefer and actively encourage charter buses. At these casinos, the proportion of charter buses is greater than the averages presented for all nine casinos.

An unusual feature of the casino bus transportation system is the pattern of bus arrivals and departures by time of day for both typical weekday and weekend conditions. As shown in Figure 2, more than one-third of all weekend bus arrivals occur between noon and 2 p.m. About 20 percent of all buses arrive in the single hour beginning at 12 noon. During the afternoon, bus arrivals decline until 7 p.m. For the next three hours, bus arrivals are more pronounced, which reflects evening visitors. Hourly variations in bus departures exhibit peaking characteristics similar to those of arrivals. The peak period (6 p.m. to 8 p.m.) includes 34.1 percent of all weekend buses. The shift in the peak reflects the standard practice of scheduling a 6-hour visit at the casino.

The weekday bus volumes by time of day exhibit a more pronounced peak than the weekend situation in terms of the number of buses and proportion of total daily buses. As shown in Figure 3, the arrival peak period occurs between 11 a.m. and 1. p.m. and includes 450 buses or approximately 40 percent of total daily buses. Arrivals decline after this peak period but exhibit a modest surge between 7 p.m. and 9 p.m. (about 10 percent). The greatest number of bus departures occurs between 5 p.m. and 7 p.m. with nearly one-fourth of all buses departing between 6 p.m. and 7 p.m.

The distribution of bus arrivals and departures reflects the efficient use of the casino buses as an integral part of each casino's marketing program. For example, most bus patrons arrive at the casino during the day when activity levels at the casino are relatively low. There is little reason to attract large numbers of bus patrons during the evening hours when most casinos are busy. The arrival of buses around noon reflects the desire for midday visitors as well as the 2- to 3-hour trip time to Atlantic City. This way, passengers board buses at relatively convenient times. The scheduled 6-hour visit of bus passengers provides ample opportunity for gambling.

Bus volumes are substantial, and the number of passengers carried is also impressive. On average, load factors vary from 35 to 40 persons on each arriving bus. On an annual basis, the casino bus transportation system carries approximately ten million visitors. During the summer, monthly patronage levels of about one million riders are attained. These figures clearly indicate the importance of the casino bus transportation system in bringing visitors to Atlantic City and the contribution the bus system makes to the economic viability of the city.

ECONOMIC IMPACTS

The primary impetus for casino gambling in Atlantic City was the encouragement of economic development and the creation of new jobs for this depressed resort community. The economic impact of gambling is apparent from the level of investment in new construction and the number of permanent jobs created. The construction cost per casino has varied from less than $100 million for renovation of existing hotels to more than $300 million for the more recent hotels and casinos that are of entirely new construction. The number of jobs created by this construction boom and the resulting economic stimulus is significant.

The introduction of casino gambling has had a substantial impact on permanent jobs. Employment levels at each casino are a function of facility size and range from 3,000 to 5,000 full-time employees. With nine operating casinos, the economic consequences of an entirely new industry are readily apparent. A complete support industry has also been created to serve the needs of the casinos and hotels in Atlantic City.

In view of the magnitude of the economic development attributable to casino gambling, those factors

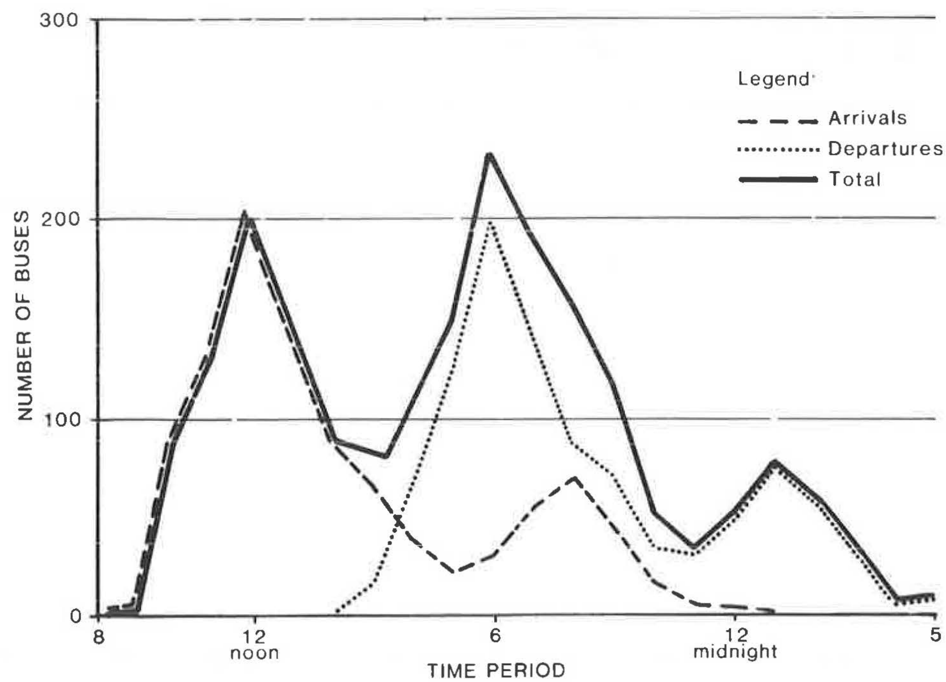


FIGURE 2 Hourly variations in bus volumes—weekend design day.

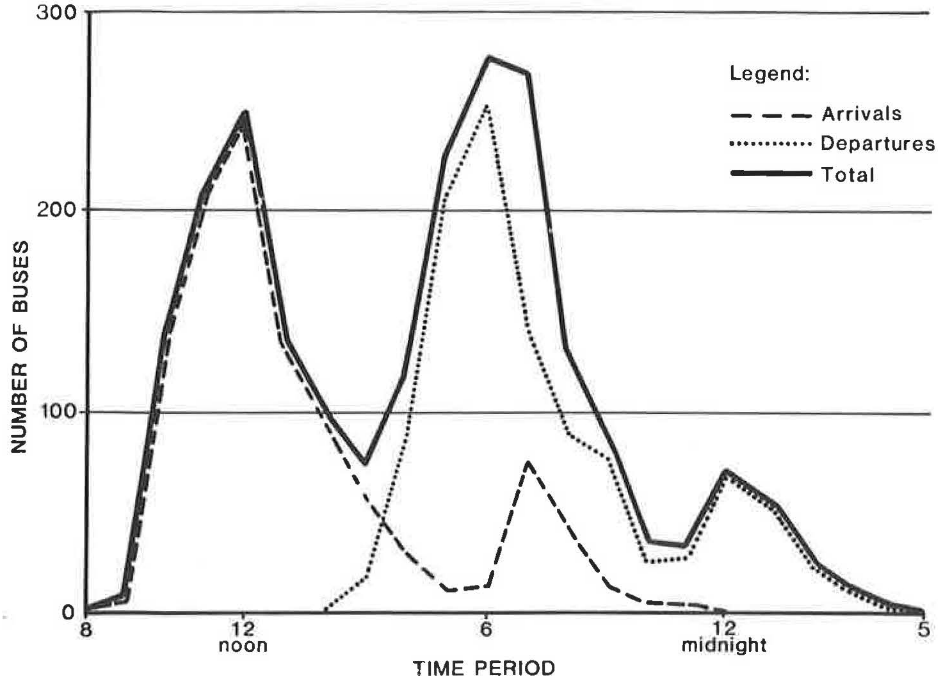


FIGURE 3 Hourly variations in bus volumes—weekday design day.

such as transportation that contribute to the success of the hotels and casinos should be recognized and encouraged. Managers at each of the casinos are aware of this fact and have implemented bus programs. As noted previously, the casino buses are an integral part of each casino's marketing and business plans. Although bus patrons are not "high rollers," they make a substantial contribution to the economic viability of the gambling industry. The casino buses draw visitors to Atlantic City during those hours of the day, days of the week, and months of the year when activity levels would be relatively low. This situation is confirmed by the hours of operation and concentration of buses during only certain time periods. Failure by the casinos to attract those ten million visitors annually would seriously impair the economic viability of the industry and jeopardize thousands of jobs.

Each casino has developed its own marketing strategy and targets for casino bus patrons. A comparison of weekday bus volumes with the size of each casino is presented in Figure 4. Two measures of casino size have been used to portray the bus marketing program. Casino floor space provides a measure of the number of persons that can be accommodated in the casino. The number of slot machines is another useful measure because the majority of bus patrons plays the slot machines rather than the various table games. Three distinct levels of marketing activity are noted for the casino bus program. Some casinos place great reliance on the casino bus program to attract visitors. This high level of casino bus activity is viewed as an essential element of the overall business plan. Other casinos place less importance on casino bus patrons and have been designated as having moderate programs. The third group of casinos has established relatively limited objectives with respect to casino buses. The number of buses is low in comparison to both floor space and slot machines.

Discussions with casino management confirm the three levels of casino bus programs. Moreover, casinos establish the cash values of incentives and

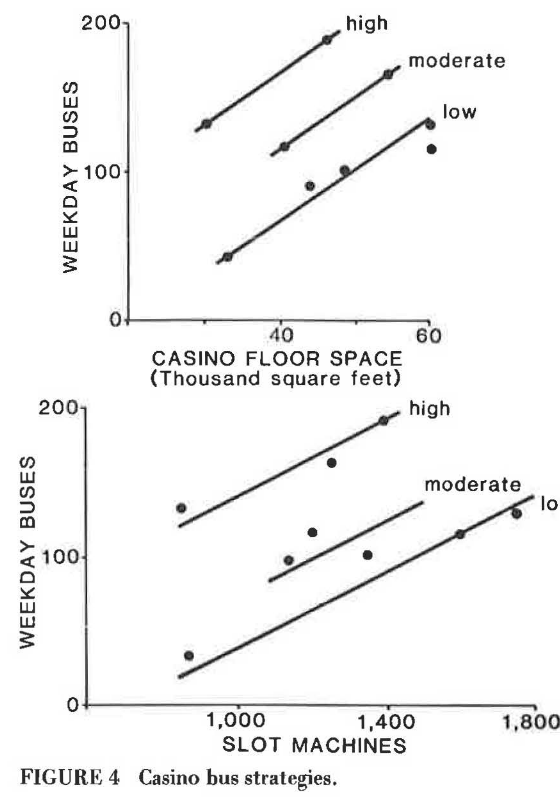


FIGURE 4 Casino bus strategies.

premiums to meet their individual casino bus objectives. For example, the casinos that emphasize attracting casino bus patrons offer coupons for more than the prevailing $10 in quarters and partial payment of meals. In contrast, those casinos that offer relatively limited incentives can reduce the number of casino bus patrons. The market is quite sensitive to changes in the premiums offered by the casinos. Bus and passenger volumes can change significantly in response to variations in the incentives offered by a particular casino relative to its competitors. These results are confirmed by the relationships shown in Figure 4.

The preceding paragraphs discuss the various strategies followed by the casinos and their reliance on bus patrons. The importance of this transportation system is confirmed by the fact that all casinos operate a bus program. To indicate the economic impact of the casino buses, the number of patrons was converted to dollars spent. The casinos do not reveal market research data, but it is generally recognized that casino bus patrons spend an average of $50 to $70 each visit. Based on ten million annual visitors, the casino bus transportation system generates tourist expenditures that exceed one-half billion dollars and could reach $700 million. Clearly the casino bus transportation system plays a major role in assuring the economic viability of the casino industry and the Atlantic City region.

GOVERNMENT ROLE

The casino buses are owned and operated by private firms that recover all costs from farebox revenue. For this reason no government funds, either operating assistance or capital funds, are required. This contrasts with urban transit systems throughout the nation as well as intercity bus carriers to a certain extent. Although government funding is not required, a regulatory role is mandated. The large volume of buses can produce traffic congestion and delays for residents. Also, the routing of buses through and the storage of buses in residential areas can be disruptive. Recognizing these problem areas, the Atlantic County Transportation Authority (ACTA) has developed a management plan for routing and parking casino buses in Atlantic City. To assure the implementation of the plan, ACTA has requested and received power to regulate the flow and movement of buses. In this way the economic and transportation benefits of casino buses can be realized while the potential adverse consequences are limited. Such an approach is unusual for a local authority, but the unique conditions brought about by casino gambling called for such innovative solutions.

CONCLUSIONS

In this paper a brief overview of the casino bus transportation system has been provided. The casino bus system serves as an important transport mode to and from Atlantic City, and it also has encouraged the economic development envisioned with casino gambling. Of particular note is the evolution of this transportation system and its operation by the private sector. It is anticipated that the dimensions and importance of the casino bus system will grow and keep pace with the development of new casinos in Atlantic City in the future. Further, the casino buses will continue to constitute a significant approach to assuring the economic vitality of the tourist industry and the region.

Publication of this paper sponsored by Committee on Intercity Bus Transportation.

Optimizing the Use of a Containership Berth

PAUL SCHONFELD and STEPHEN FRANK

ABSTRACT

Total system costs, including those of berths, cranes, storage yards, dock labor, ships, containers, and cargo, are minimized for single-berth containership terminals under various assumptions. The analytic model accounts for queueing delays to ships, mutual interference among cranes, minimum work shifts, and storage yard requirements. Results indicate that total system costs per ship or per ton of cargo can be significantly decreased by increasing the number of cranes per berth and berth use above current levels. The results are especially sensitive to labor costs and work rules.

Containerization has been widely adopted in ocean shipping since the late 1950s because it offers some compelling advantages over break-bulk shipping. By handling the cargo in relatively large standardized intermodal containers, the time and cost of transferring cargo in ports can be reduced substantially. The cost and weight of cranes required to handle containers preclude their installation on modern specialized containerships. Thus, unlike older ships, most containerships have no self-loading or self-unloading capability.

Given the high cost of containerships and terminal facilities, it is desirable to use both ships and terminals as efficiently as possible. However, some current plans for containerport development may lead to underuse of containerport capacity as well as suboptimal turnaround times for ships. Typically such plans include the construction of large numbers of berths relative to the ship arrivals forecast. Some containerports seem to provide too many berths for the expected number of ships (e.g., 1.4 berth days per ship arrival is typical) and too few cranes (e.g., 1.43 cranes per berth at one modern facility). The combination of too many berths and too few cranes may result in underused port capacity and needlessly long turnaround times for ships. The theory presented here is that, for a given rate of ship arrivals, fewer berths and more cranes per berth would provide a better solution by reducing the capital cost of berths as well as reducing the total time each ship spends in port. To test that hypothesis, a mathematical model was developed to determine total system costs under a wide range of assumptions and circumstances, and to optimize the ratios of ships to berth and cranes to berth. In this paper the simplest version of the model and some initial results obtained with it are presented. The results presented here are limited to one-berth terminals. (The model has been extended to multi-berth terminals, for which results will be published soon.) Such results are useful because many small ports and many private companies in large ports operate one-berth terminals.

LITERATURE REVIEW

Several authors including Plumlee (1), Nicolau (2), and Wanhill (3) have sought to optimize the number of general-cargo berths in a port by minimizing a sum of port costs and ship delays. Fratar, Goodman, and Brandt (4), Jones and Blunden (5), and Miller (6) have investigated the applicability of various queueing models and statistical distributions for arrival and service rates. Queueing theory has been applied by Wilson (7) to lock capacity analysis and by Freund (8) to barge fleeting operations.

Boyer (9) discusses various aspects of containerization including berth use and productivity. Boyer defines berth use as ship calls per week divided by 7 days per week rather than occupied hours divided by total hours per week. He also suggests that four ship calls per week represent practical berth capacity and that "scheduling beyond four days (i.e., four ships per week) means that ships will frequently be kept waiting for berths, and containership operators will not tolerate delays." Furthermore, he states that "one crane (i.e., per ship) operating on a single shift will handle this demand (i.e., four ships per week) with time to spare" (9,p.463). These two statements do not seem fully consistent. The results presented here indicate that with more cranes per berth more than four ships per week can be handled without unacceptable delay, especially if the savings in facilities costs can be passed to shipowners through reduced port charges.

MODEL FORMULATION

The optimization of containerport design and operation requires trade-offs among several important elements, including berths, cranes, storage facilities, work crews, ships, containers, and cargo. Interaction, both competitive and cooperative, with surface transportation and other ports should also be considered in a complete analysis, although a relatively simple model can incorporate most of the important cost relations. The full capacity of a port and its components cannot be used without imposing excessive delays on ships. Because ship arrival rates, container handling (or transfer) rates, and the number of containers transferred per ship are all stochastic variables, there are inevitably times when ships must wait in queues for a berth to become available. To properly balance the costs of delays to ships and cargo versus the cost of facilities, a total system cost function can be formulated. This function can be used to summarize the total costs to the relevant parties (shipowners, shippers, and port operators). A subset of this total cost function may be used in conjunction with appropriate revenue functions to optimize the system from a narrower viewpoint, for example, that of a port authority. It should be noted that some companies own and operate both containerships and terminal facilities and hence would be concerned with the combined cost of ships and terminals.

The total cost function consists of the following six components:

$$C = C_b + C_r + C_y + C_\ell + C_s + C_u \quad (1)$$

where, in dollars per hour,

C = total system cost,
C_b = berth cost,
C_r = cost of cranes,
C_y = cost of storage yards,
C_ℓ = labor cost for crane gangs,
C_s = cost of ships in port, and
C_u = cost of containers and their cargo.

Using the definitions of variables presented in Table 1, these cost components may be formulated as follows.

$$C_b = bB \quad (2)$$

$$C_r = bnR \quad (3)$$

$$C_y = zaY \quad (4)$$

$$C_\ell = \lambda n\ell L \quad (5)$$

$$C_s = \lambda sS \quad (6)$$

$$C_u = \lambda spU \quad (7)$$

The cost per berth hour B of Equation 2 is obtained by multiplying the initial berth cost B_i by the capital recovery factor to get the yearly cost, adding the annual maintenance cost M_b, and dividing the entire sum by 365 x 24 hours per year.

$$B = \left(\left\{B_i\,[i\,(1+i)^N]/[(1+i)^N - 1]\right\} + M_b\,(365 \times 24)\right)/(365 \times 24) \quad (8)$$

The cost per crane hour R in Equation 3 is similarly derived from the initial and operating costs of individual cranes, although the economic lifetime of cranes is usually shorter than that of berths.

The required container capacity of the storage yard (z in Equation 4) is the product of ship arrival rate λ, containers exchanged per ship x, average yard dwell time d, and a safety factor d_s:

$$z = \lambda x d d_s \quad (9)$$

The safety factor d_s provides sufficient yard capacity for larger than average λ, x, and/or d. Alternatively, for a given yard capacity z, the maximum allowable average dwell time d_{max} is obtained by letting d_s = 1.0 and dividing Equation 9 by λx:

$$d_{max} = z/\lambda x \quad (10)$$

The maximum λ or x allowed by the yard storage capacity can be similarly determined from Equation 9.

Transfer (i.e., loading and unloading) time of a ship depends on the number of containers x exchanged per ship at that terminal; the container handling rate y, which is also called the crane cycle time; and the number of cranes n servicing the ship. If the cranes could operate without mutual interference and if the work load were equally distributed among the n cranes, the transfer time would be

$$t = xy/n \tag{11}$$

However, because interference may occur, especially truck movements under the cranes, and because the containers are unlikely to be evenly distributed in the ship, the following function is used in this model:

$$t = xy/n^f \tag{12}$$

in which the exponent F may be less than 1.0. A typical f value of 0.85 means that 2 cranes can do $2^{.85}$ = 1.8 times the work of one crane, three cranes can do $3^{.85}$ = 2.54 times the work of one crane, and so on. Although the interference function may not be precisely known for large values of n, its possible implications can be examined through parametric analysis. An f value of 1.0 in Equation 12 is equivalent to assuming no interference and reverting to Equation 11.

The labor cost C_ℓ (Equation 5) is determined either by the service time t or the minimum shift duration ℓ_{min}, which is typically 4 hours. Hence the labor time ℓ (in hours per ship) is expressed as

$$\ell = \mathrm{Max}\,(t, \ell_{min}) \tag{13}$$

In Equation 5 ℓ is multiplied by the number of crane gangs per ship n, which is equal to the number of cranes per ship; by the cost per gang hour L; and by the ship arrival rate λ to obtain the total labor cost per hour C_ℓ.

The total service time μ includes the container transfer time to as well as the maneuvering (i.e., docking and undocking) time m, during which the berth is inaccessible to other ships. The service rate μ is therefore

$$\mu = 1/(t + m) \tag{14}$$

The average time that a ship spends in port is the sum of the service time 1/μ and the queue wait time w. Queue wait time depends on arrival and service rates, on the number of berths, and on the distributions of arrival rates and service times. Simple functions for the queue wait time are available for any service time distributions (including arbitrary distributions the standard deviation of which is known) for single-server cases (10). For multiserver cases, a simple wait time function is available for exponential service times only (10), but several studies (4-6) confirm that exponential service times are applicable. Those studies also verify the applicability of Poisson arrival times. In the single-berth case analyzed here, Poisson arrivals and exponential service times mean that the queue wait time is

$$w = [1/(\mu - \lambda)] - 1/\mu \tag{15}$$

and that the average time in port is

$$s = w + 1/\mu = 1/(\mu - \lambda) \tag{16}$$

Port time s is a factor in ship costs (Equation 6) as well as shipper costs (Equation 7). For each hour in port, a ship incurs depreciation, crew, auxiliary power, insurance, and other costs, totaling S \$/hr, which is multiplied by the time in port s to obtain the cost per ship. That in turn is multiplied by the hourly ship arrival rate λ to obtain the hourly cost C_s for all ships idling in port (Equation 6).

Similarly, to obtain the time cost C_u for all containers on board ships (Equation 7), multiply p, the average number of containers on board each ship (not the number exchanged) by the hourly cost (i.e., value of time) of containers U, the port time per ship s, and the ship arrival rate λ. The hourly cost of containers is a weighted average of the capital recovery factors (Equation 8) for all cargoes and containers, including empty containers. A weighted average accounts for widely differing values for different types of cargo and for the relatively high time value of cargoes with short economic lifetimes (e.g., perishables and rapidly obsolescing items).

The foregoing formulation provides a cost model more comprehensive than those of Plumlee (4), Nicolau (5), and Wanhill (6). It would be desirable to model and optimize the storage element in more detail because a reduction in container dwell time would reduce (a) the size and cost of the storage yard, (b) the time cost (depreciation and interest) for stored containers, and (c) the average length of movements within the yard.

It should be noted that the model is simple enough that the cost for any combination of input variables can easily be computed with a nonprogrammable calculator. A personal computer can be, and has been, programmed to run the model.

PARAMETER VALUES

The baseline analysis used the parameter values given in Table 1. These values are based on information obtained from trade publications and port plans, discussions with port officials, and Maritime Administration data on ship costs. In very few cases (e.g., for the lifetimes of cargoes in containers) there was no reliable data and estimates were used. Although the baseline parameter values are typical, their precision is not critical in this paper because the basic conclusions hold for a wide range of values. For specific applications, model users should, of course, input the best available values and use sensitivity analysis to check how changes in parameter values affect their decisions.

The baseline values (Table 1) for the berth costs (B = \$350/hr) assume the initial berth cost is \$28 million, the interest rate is 12 percent, the economic life is 40 years, and the annual maintenance cost is about 10 percent of the initial cost. The same values, except for an initial cost of \$200,000 per acre, are used to obtain an initial cost of \$12 million and hourly cost of \$150 for a 60-acre storage yard. At 12 percent interest, lifetimes beyond 30 years have very little additional effect on hourly costs. However, the hourly costs of containers and cargoes are sensitive to the shorter assumed weighted average lifetimes of 7 and 3 years, respectively. Containers are assumed to cost \$5,000 initially, and the average cargo value is assumed to be \$30,000 per container.

RESULTS

The model presented here was used mainly to examine the effects of the number of cranes n, ship arrival rate λ, and various exogenous parameters on total system costs. Four cases were defined using the following assumptions.

A--No interference among cranes and no minimum labor shift,
B--No interference among cranes and a 4-hr minimum shift,
C--Mutual interference among cranes and no minimum labor shift, and
D--Mutual interference among cranes and a 4-hr minimum shift.

These cases represent assumptions that range from quite ideal (A) to quite realistic (D). Case D offers the most useful baseline for practical results under currently prevailing conditions. Using the baseline parameter values from Table 1, Figure 1 shows how the total system cost C varies with the number of cranes n in the four cases A, B, C, and D, and also in case D' that has a more extreme interference parameter (f = 0.7 instead of 0.85 in cases C and D, and 1.00 in cases A and B). The optimal (i.e., minimum total cost) number of cranes n is circled on the cost curves. As should be expected, case A has the lowest cost at any number of cranes n. It is notable that, without 4-hr minimum shifts in cases A and C, the costs are lowered by using more cranes during shorter transfer times. In cases B and D, with 4-hr minimum shifts, it is not cost-effective to seek transfer times below 4 hr, and the optimal number of cranes is whatever will bring the transfer time t (Equation 12) close to 4 hr. As the minimum shift duration decreases, the optimal number of cranes increases and total cost decreases.

As expected, with mutual interference among cranes in cases C and D, costs are higher than in the corresponding cases A and B without interference. Cases B, D, and D' show the increase in costs as the interference exponent f goes from 1.0 (i.e., no interference) to 0.70 in D'. The increase in interference increases the optimal number of cranes n* only enough to bring the transfer time down to about 4 hr, which is the minimum shift in cases B, D, and D'. (All parameters other than f are also equal in those three cases.)

Figures 2 and 3 show the effect of the number of cranes on the relative magnitude of the various cost components and the composition of the total cost in case D. In Figure 2 ship cost C_s and container user cost C_u decrease sharply as additional cranes reduce the transfer time in port. The crane cost C_r increases proportionally with n. The labor cost C_L also increases proportionally with the number of cranes when many cranes are used because each crane's labor gang is paid for 4 hr even though the transfer time decreases with n. At small values of n (1 and 2 cranes) the labor cost does not decrease proportionally with n because the small number of cranes requires shifts longer than 4 hr. The berth cost C_b and storage yard cost C_y do not vary at all with the number of cranes used.

Figures 4 and 5 show for cases A and D, respectively, the sensitivity of the total costs C and of the optimal number of cranes n* to a 50 percent increase in various parameters. Of interest here are the cost parameters for berths B, cranes R, ships S, containers and their cargo U, labor L, the average ship payload p, and the exchange volume x. As each of these parameters is increased by 50 percent, the total costs increase and the optimal number of cranes n* changes in the expected direction. Specifically, n* tends to increase as the ship cost S, container cost U, ship payload p, and exchange volume x increase; and n* tends to decrease as crane

TABLE 1 Variables

Symbol	Definition	Baseline Value
a	Number of acres of storage yard per container	0.0177
b	Number of berths in terminal	1
B	Hourly berth cost ($)	350
B_i	Initial berth cost ($)	28,000,000
C	Total system cost ($/hr)	
$\overline{C}$	Average system cost ($/ship served)	
C_b	Berth cost ($/hr)	
C_ℓ	Dock labor cost ($/hr)	
C_r	Cost of cranes ($/hr)	
C_s	Cost of ships in port ($/hr)	
C_u	Cost of containers and cargo	
C_y	Cost of storage yards ($/hr)	
d	Average yard dwell time (hr/container)	
d_{max}	Allowable yard dwell time (hr/container)	
d_s	Dwell margin	
f	Crane interference exponent	0.85
i	Interest rate	0.12
ℓ	Paid labor time (hr/gang/ship)	
ℓ_{min}	Minimum shift duration (hr)	4
L	Labor cost ($/gang hour)	600
m	Maneuver (docking and undocking) time (hr/ship)	1.0
M_b	Annual maintenance cost per berth	2,800,000
n	Number of cranes per berth	
n*	Optimal number of cranes per berth	
N	Economic lifetime (yr)	
P	Average payload (containers/ship)	600
R	Crane cost ($/crane hr)	42
s	Average time in port (hr/ship)	
S	Ship cost in port ($/ship hr)	700
t	Container transfer time (hr/ship)	
U	Average cost of container and its contents ($/container hr)	1.50
w	Average queueing time (hr/ship)	
x	Exchange volume (containers transferred/ship)	180
y	Crane cycle time (hr/container)	0.045
Y	Storage yard cost ($/acre hr)	2.5
z	Number of container slots per berth	
λ	Arrival rate (ships/hr)	0.1
μ	Service rate (ships/hr)	

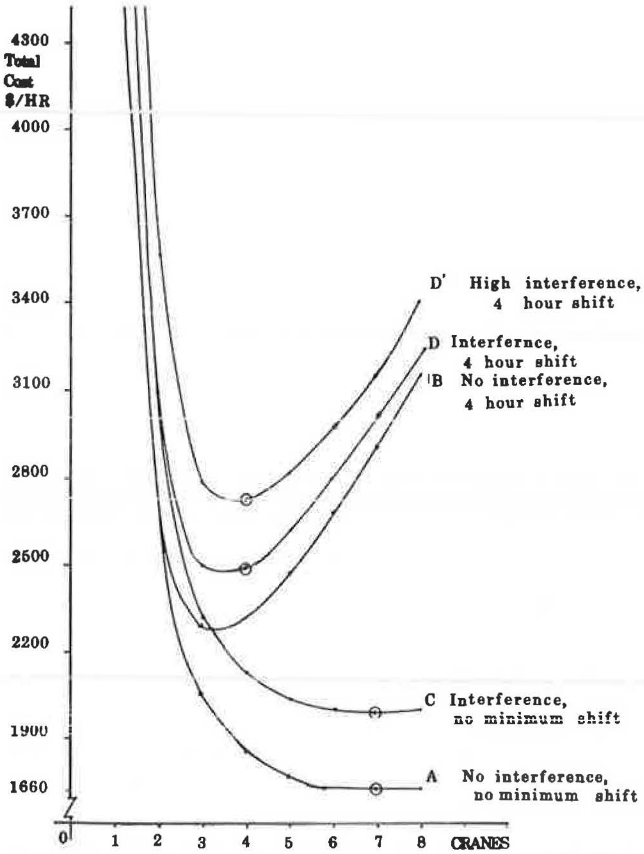


FIGURE 1 Total costs for various assumptions and numbers of cranes.

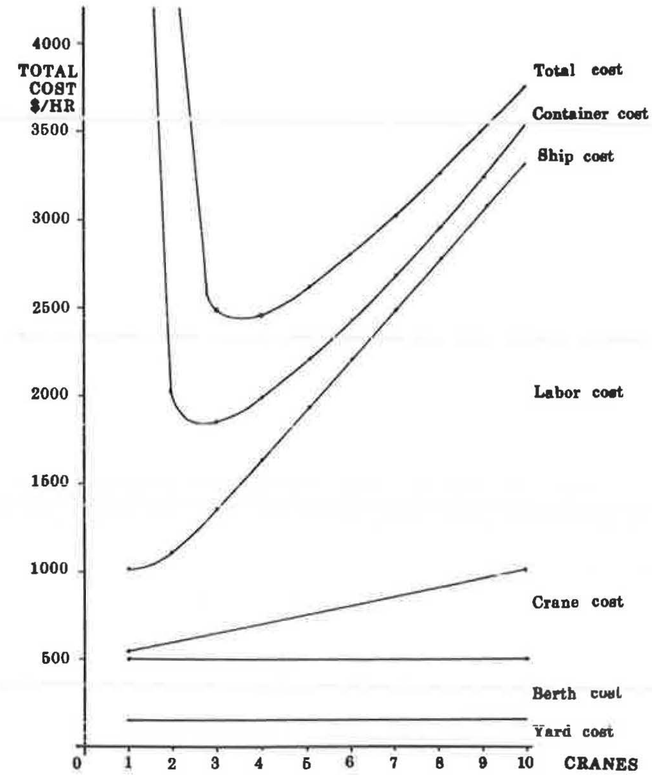


FIGURE 3 Composition of total costs: case D.

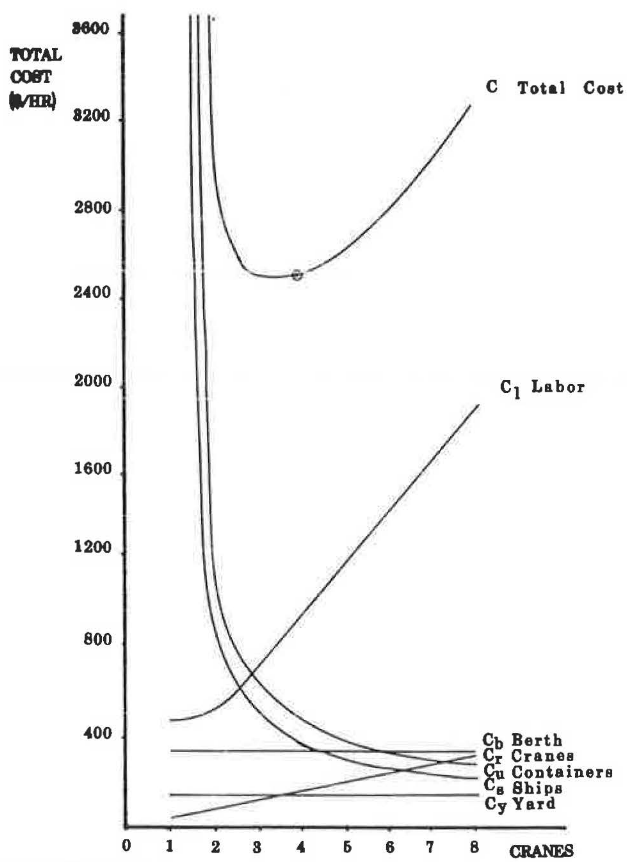


FIGURE 2 Variation of cost components with number of cranes: case D.

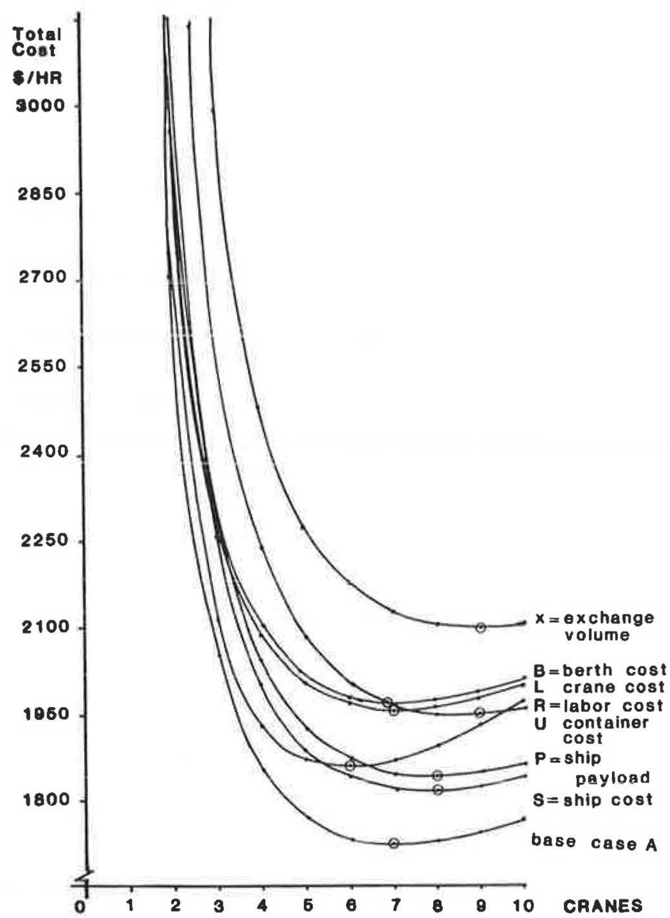


FIGURE 4 Sensitivity of total costs to a 50 percent increase in major parameters: case A.

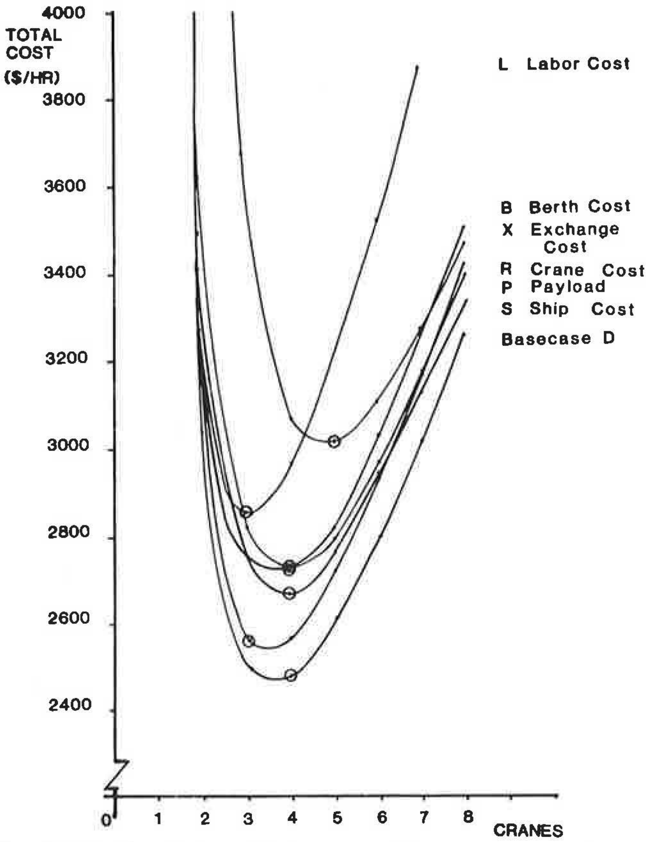


FIGURE 5 Sensitivity of total costs to a 50 percent increase in major parameters: case D.

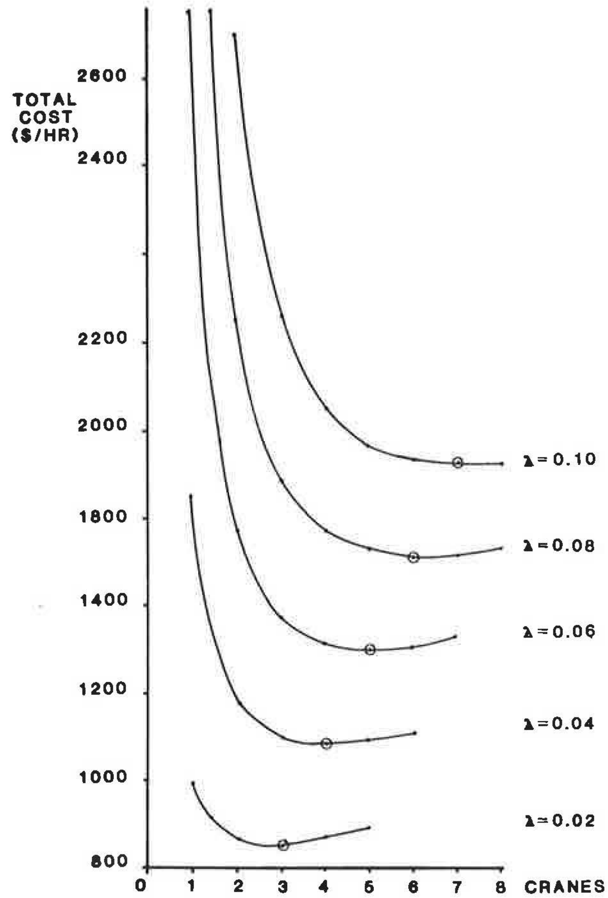


FIGURE 6 Total costs for various ship arrival rates: case A.

cost R and labor cost L increase. An increase in berth cost B (and/or yard cost Y) simply shifts the whole curve upward without shifting the optimal number of cranes n* at its minimum point (Figure 2).

Figures 6-9 show the effects of ship arrival rate λ on the optimal number of cranes n*, on total costs (Figures 6 and 8), and on the average cost per ship served $\bar{C}$ (Figures 7 and 9). The average cost is the total cost C divided by the arrival rate λ:

$$\bar{C} = C/\lambda \quad (17)$$

Although total costs (Figures 6 and 8) always increase with λ, the average cost (i.e., the total system cost per served ship) decreases with λ up to higher values of λ than are encountered in current port practice. Thus in case D (Figure 9) the cost per ship $\bar{C}$ continues to decrease up to arrival rates of approximately 0.1 ship per hour (= 2.4 ships per day = 72 ships per month). The most cost-effective arrival rate per berth would be even higher in multiple-berth terminals.

The assumption of exponential service times may also exaggerate somewhat the queueing delays and lead to a slight underestimate of the optimal ships to berth ratio. Figures 6 through 9 also show, as expected, that the optimal number of cranes n* increases as the arrival rate increases. For the realistic case D, the optimal combination, in terms of total system cost per ship served, is approximately 0.1 ship per hour (16.8 ships per week) and 4 cranes at the one-berth terminal. This represents more intensive berth use than the four ships per week limit suggested by Boyer (9) and involves more cranes per berth than are currently provided at most

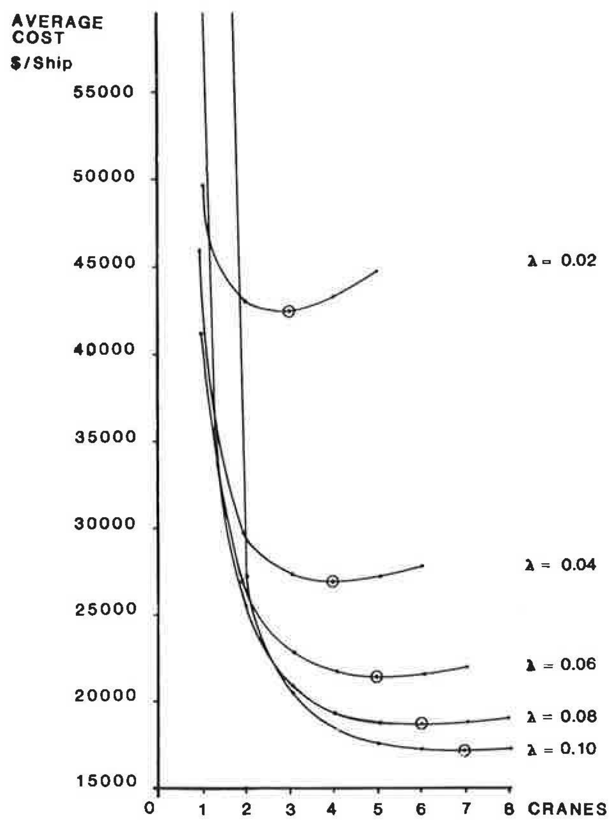


FIGURE 7 Average costs for various ship arrival rates: case A.

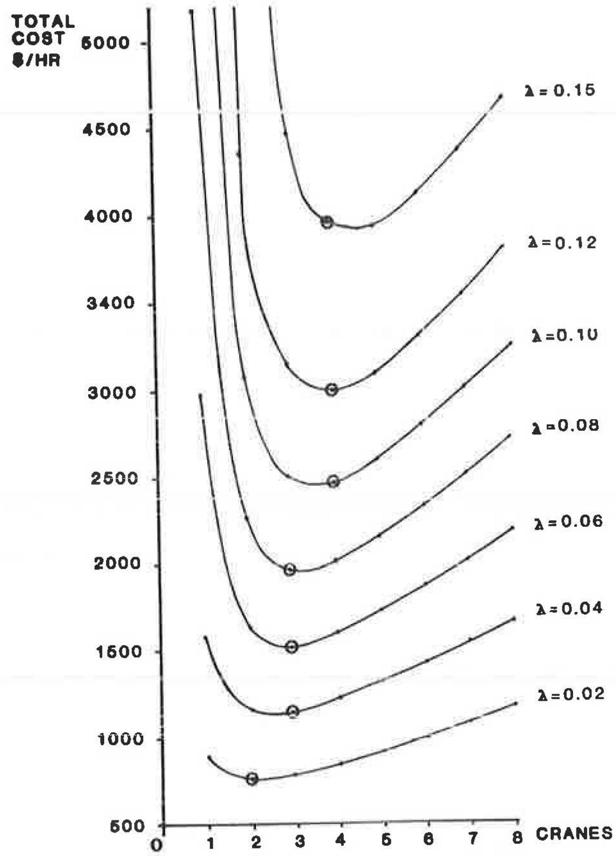


FIGURE 8 Total costs for various ship arrival rates: case D.

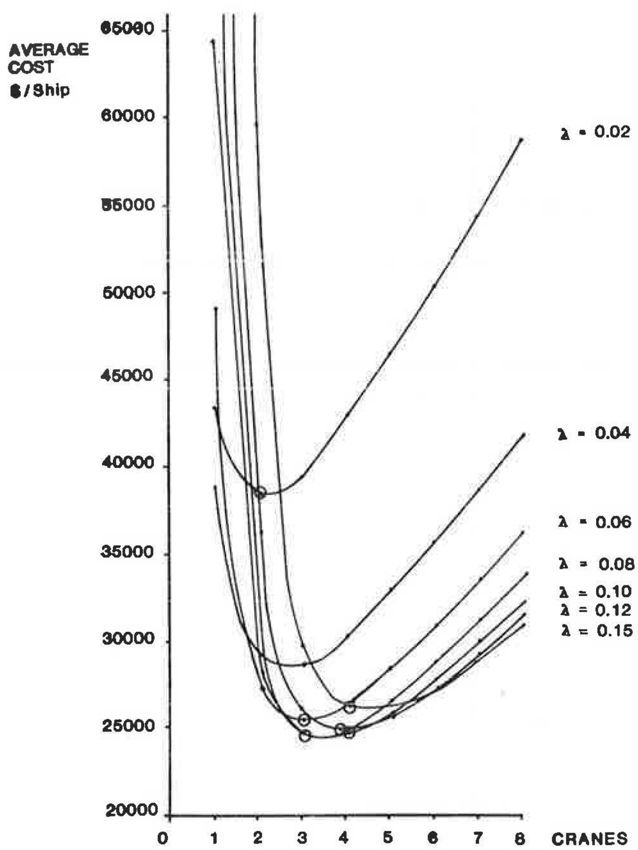


FIGURE 9 Average costs for various ship arrival rates: case D.

terminals. The assumption that container transfer operations can proceed 24 hours per day 365 days per year is implicit in the results obtained from Boyer's guidelines (9), and much current practice would appear more reasonable if that assumption were truly unrealistic.

CONCLUSIONS

The results presented here indicate that the total system cost per ship (or per container, or per ton) served could be decreased by increasing the number of cranes per berth and berth use (e.g., by building fewer berths for a given ship arrival rate) considerably beyond present levels. These results are especially sensitive to institutional factors such as the minimum duration of labor shifts and the possibility of working around the clock. The effects of other parameters on the optimal number of cranes, optimal berth use, and system costs can also be analyzed with the model developed here.

With appropriate modifications, this model could also be used to examine multiple-berth terminals with variable-length berths, improved crane interference functions and service time distributions, storage yard operation, and the possibility of having labor gangs work on more than one ship per shift.

REFERENCES

1. C.H. Plumlee. Optimum Size Seaport. Journal of the Waterways and Harbors Division, ASCE, Vol. 92, No. WW3, Aug. 1966, pp. 1-24.
2. S.N. Nicolau. Berth Planning by Evaluation of Congestion and Cost. Journal of the Waterways and Harbors Division, ASCE, Vol. 93, No. WW4, Nov. 1967, pp. 107-132.
3. S. Wanhill. Further Analysis of the Optimum Size Seaport. Journal of the Waterways, Harbors, and Coastal Engineering Division, ASCE, Vol. 100, No. WW4, Nov. 1974, pp. 377-383.
4. T.J. Fratar, A.S. Goodman, and A.E. Brandt. Prediction of Maximum Practical Berth Occupancy. Transactions, ASCE, Part IV, Vol. 125, 1961.
5. J.H. Jones and W.R. Blunden. Ship Turn-Around Time at the Port of Bangkok. Journal of the Waterways and Harbor Division, ASCE, Vol. 94, No. WW2, May 1968, pp. 135-148.
6. A.J. Miller. Queueing at Single-Berth Shipping Terminal. Journal of the Waterways, Harbors, and Coastal Engineering Division, ASCE, Vol. 97, No. WW1, Feb. 1971, pp. 43-56.
7. H.G. Wilson. On the Applicability of Queueing Theory to Lock Capacity Analysis. Transportation Research, Vol. 12, 1978, pp. 175-180.
8. D.M. Freund. Queueing Theory in Barge Fleeting Operations. Compendium of Technical Papers, 51st Annual ITE Meeting, Aug. 1981, pp. 254-262.
9. W.C. Boyer. Containerization--A System Still Evolving. Journal of the Waterways, Harbors, and Coastal Engineering Division, ASCE, Vol. 98, No. WW4, Nov. 1977, pp. 461-473.
10. F.S. Hillier and G.J. Lieberman. Introduction to Operations Research. Holden-Day, San Francisco, Calif., 1967.

Publication of this paper sponsored by Committee on State Role in Waterborne Transportation.

Dial-a-Ride and Bus Transit Services: A Mode-Choice Analysis

MARCIA C. WILDS and WAYNE K. TALLEY

ABSTRACT

Because of the anticipated reduction in federal assistance funds, mass transit carriers in some localities are considering replacing or supplementing mass transit services with less costly paratransit services. In planning the addition of paratransit services, transit planners should be aware of those factors that affect an individual's choice of mass transit or paratransit services. A logit analysis of the factors that affect individuals' choice of bus transit or dial-a-ride paratransit services is presented. It is concluded that passenger perception of the reliability of dial-a-ride and bus transit and the accessibility of bus transit are primary factors that affect this decision.

Government assistance funds to the U.S. mass transit industry have, in recent years, allowed the industry to reverse the postwar trend of declining ridership. Federal transit assistance funds, however, are scheduled to be drastically cut by the Reagan administration. Federal transit capital assistance funds in 1982-1985, for example, are expected to be $4 billion less than what was recommended by the Carter administration, and federal transit operating assistance funds are expected to be reduced substantially until they are finally eliminated after the 1985 fiscal year (1,p.7). Transit carriers suggest that these budget cuts are "the rebirth of the vicious cycle that put private transit operators out of business twenty-five years ago--where you raise your fares and cut your services to lower costs and then end up carrying fewer riders" (2,p.6).

With cutbacks in government assistance funds, mass transit carriers will be forced to increase fares to maintain service. In addition, some mass transit carriers are considering replacing their mass transit services on marginal routes with less costly paratransit services. Mass transit service is a fixed-route, scheduled, passenger service as provided by bus, heavy rail, and light rail systems. Paratransit services may be nonscheduled or variable-route passenger services (3,p.319).

A paratransit service that has been proposed as a replacement for mass transit service in relatively low-density areas and as a feeder service to mass transit's fixed-route systems is dial-a-ride (4-6). Dial-a-ride paratransit includes shared-ride taxi and demand-responsive bus services. The customary method of hailing this service is by telephone. Dial-a-ride service may be provided on immediate request, or passengers may be required to make requests at least a few hours before their desired trip time. The dispatcher of a dial-a-ride system then dispatches vehicles to collect and distribute passengers from and to their requested origin-destination points. Door-to-door service is provided (i.e., passengers are picked up at their homes and delivered to the door of their final destinations). For shared-ride taxi service, the trend has been for a publicly owned mass transit carrier to contract with a local taxicab operator to provide the service. The publicly owned mass transit carriers, in turn, are eligible for federal capital and operating assistance funds.

In planning whether to replace mass transit service with dial-a-ride service, transit planners should be aware of the factors that affect the likelihood of passengers switching from mass transit to dial-a-ride services. The purpose of this paper is to investigate such factors. Specifically, those factors that affect individuals' choice of fixed-route bus transit or dial-a-ride services will be investigated. Previous mode-choice studies have been concerned primarily with automobile and mass transit services (7-10); hence, little attention has been devoted to mode choice between mass transit and paratransit services. One exception is a study by Gordon, Williams, and Theobald (11), which concluded that dial-a-ride had a chance of being implemented in East Los Angeles, because it offered greater comfort and security than do conventional mass transit services.

THE MODEL

Assume the utility function U_{dj} of the jth individual using dial-a-ride transit service for a given trip may be expressed as

$$U_{dj} = \alpha_0 + \beta_1 P_{dj} + \beta_2 T_{dj} + \beta_3 C_{dj} + \beta_5 R_{dj} \qquad (1)$$

where

- P_{dj} = price of a given dial-a-ride trip for the jth individual,
- T_{dj} = travel time of a given dial-a-ride trip for the jth individual,
- C_{dj} = perception of the noncrowdedness of a given dial-a-ride trip for the jth individual, and
- R_{dj} = perception of the reliability of a given dial-a-ride trip for the jth individual.

Similarly, assume the utility function U_{bj} of the jth individual using fixed-route bus transit service for a given trip may be expressed as

$$U_{bj} = \gamma_0 + \beta_1 P_{bj} + \beta_2 T_{bj} + \beta_4 C_{bj} + \beta_6 R_{bj} + \beta_7 A_{bj} \qquad (2)$$

where

- P_{bj} = price of a given bus transit trip for the jth individual;
- T_{bj} = travel time of a given bus transit trip for the jth individual;
- C_{bj} = perception of the noncrowdedness of a given bus transit trip for the jth individual;

R_{bj} = perception of the reliability of a given bus transit trip for the jth individual; and
A_{bj} = bus transit accessibility, or distance from home to the nearest bus stop, for the jth individual.

Further, assume that the relative probability (P_j/ $1-P_j$) that the jth individual will choose dial-a-ride rather than bus transit for a given trip may be expressed as

$$P_j/1-P_j = e^{U_{dj}}/e^{U_{bj}} \quad (3)$$

where

P_j = probability that the jth individual will choose dial-a-ride rather than bus transit service for a given trip and
$1-P_j$ = probability that the jth individual will choose bus transit rather than dial-a-ride service for a given trip.

Taking the natural log of Equation 3 and rewriting give

$$\ln (P_j/1-P_j) = U_{dj} - U_{bj} \quad (4a)$$

or

$$\ln (P_j/1-P_j) = \beta_0 + \beta_1(P_{dj}-P_{bj}) + \beta_2(T_{dj}-T_{bj}) + \beta_3C_{dj} - \beta_4C_{bj} + \beta_5R_{dj} - \beta_6R_{bj} - \beta_7A_{bj} \quad (4b)$$

where $\beta_0 = \alpha_0 - \gamma_0$.

Equation 4b is an example of a logit statistical model whose parameters will be estimated to investigate passenger choice of dial-a-ride or fixed-route bus transit services. The dependent variable, $\ln(P_j/1-P_j)$, has been referred to in the literature as the logit variable and for Equation 4b may be interpreted as the log of the odds ratio that the jth individual will choose dial-a-ride rather than bus transit for a given trip. The signs of the $P_{dj} - P_{bj}$ and $T_{dj} - T_{bj}$ coefficients in Equation 4b are expected to be negative, because increases in the price and travel time of dial-a-ride relative to those of bus transit are expected to decrease the odds of an individual choosing dial-a-ride rather than bus transit. The expected sign of the C_{dj} coefficient is positive, because an improvement in dial-a-ride noncrowdedness is expected to increase the odds of an individual choosing dial-a-ride. Conversely, the sign of the C_{bj} coefficient (i.e., $-\beta_4$) is expected to be negative, because an improvement in bus transit noncrowdedness is expected to decrease the odds of an individual choosing dial-a-ride rather than bus transit. Similarly, the signs of the dial-a-ride reliability coefficient (β_5) and the bus transit reliability coefficient ($-\beta_6$) are expected to be positive and negative, respectively. Finally, the expected sign of the A_{bj} coefficient (i.e., $-\beta_7$) is positive, because, as distance from home to the bus stop increases, the odds of selecting dial-a-ride increase.

EMPIRICAL RESULTS

The data for this study were extracted from the 1977 TELTRAN Impact Study (12) conducted by the Institute for Social Research of the University of Michigan and the Ann Arbor Transportation Authority. The data contain information on the travel behavior of Ann Arbor residents and their perceptions and evaluations of the available transit alternatives including dial-a-ride and bus transit.

The travel time variable (T_j) measures the total travel time (i.e., it may include in-transit, waiting, walking, and transfer times for a given trip). Because the total or aggregated travel time only was available in the data set, individual time components could not be considered in the following mode-choice analysis. If an observation for the T_j variable was missing, an estimate was made by calculating the average mile-per-hour by bus and dial-a-ride using the harmonic mean. The use of the harmonic mean is appropriate for measures involving speed (13). A travel time estimate was then computed by dividing the passenger's distance from home to work (or home to shopping area) by the average mile-per-hour for the given transportation service. Travel time is measured in minutes. Furthermore, because the price of bus transit and dial-a-ride for a given passenger trip is the same in the data set, the price variable (P_j) will always be zero and therefore will not be considered in these estimations. The C_{bj} and C_{dj} variables are dummy variables that consider the relative noncrowdedness of bus and dial-a-ride trips, respectively, for the jth individual. Individuals in the data set were asked to indicate their perception of the noncrowdedness of a bus or dial-a-ride vehicle by using a rating scale from zero to five (i.e., a zero was to be assigned if the bus or dial-a-ride vehicle was never crowded and a five if it was always crowded). This rating scale was transferred to a dummy-variable format by assigning a one to C_{bj} or C_{dj}, denoting noncrowdedness, if the rating was between zero and two and assigning a zero to C_{bj} or C_{dj}, denoting crowdedness, if the rating was between three and five. This transformation format was used to give equal weight to the response categories of the rating scale (i.e., the response categories from zero to two are three in number and the response categories from three to five are three in number).

The R_{bj} and R_{dj} variables are dummy variables that consider the relative reliability of bus and dial-a-ride services. Individuals in the data set were asked to indicate their perception of the reliability of bus and dial-a-ride services by using a rating scale from zero to five (i.e., a zero was to be assigned if the bus or dial-a-ride service was perceived to be reliable and a five if it was perceived to be unreliable). This rating scale was transferred to a dummy-variable format by assigning a one to R_{bj} or R_{dj}, denoting reliability, if the rating was between zero and two and assigning a zero to R_{bj} or R_{dj}, denoting unreliability, if the rating was between three and five. Bus accessibility (A_{bj}) is the distance (measured in miles) from the home of the jth individual to the nearest bus stop. An accessibility variable for dial-a-ride service was not considered, because this service is perfectly accessible (i.e., dial-a-ride vehicles pick up passengers at their homes).

Estimations of two forms of logit Equation 4b, based on a sample of 28 work trips (using dial-a-ride and bus transit services), are given in Table 1. (The shorter form of Equation 4b is $\ln(P_j/1-P_j) = \beta_5R_{dj} - \beta_6R_{bj} - \beta_7A_{bj}$.) A sample of 28 work trips was constructed from the data set by deleting all work trips where observations on the explanatory variables (except the travel time variable) were missing. The computer package SHAZAM (14) was used to obtain the logit estimates. As stated previously, the variable P_j is deleted, because the price of bus and dial-a-ride services for a given trip is identical. For Equation 4b in Table 1, the variables R_{dj} and A_{bj} are significant (based on one-tailed tests) at the 0.10 level; the variables T_j, C_{dj}, and

TABLE 1 Logit Estimation for Work Trips

Explanatory Variable	Logit Coefficient	
	Equation 4b	Shorter Form
Constant	-6.75 (-1.55)	-2.02 (-1.81)
T_j	-.098 (-1.13)	
C_{bj}	2.94 (.737)	
C_{dj}	4.83 (1.15)	
R_{bj}	-6.98 (-1.31)	-2.78 (-1.83)
R_{dj}	3.63 (1.49)	2.58 (1.69)
A_{bj}	.186 (1.67)	.085 (2.07)
LRS	14.85	9.69
AOP	89%	86%

Note: t-coefficients are shown in parentheses, LRS = likelihood ratio statistic, and AOP = accuracy of prediction.

R_{bj} are significant at the 0.20 level. All coefficients of Equation 4b, except that of the variable C_{bj}, have the expected sign; however, C_{bj} is insignificant at the 0.20 level of significance. The sign of the T_j coefficient indicates that as travel time of dial-a-ride increases relative to that of bus transit, the odds of an individual choosing dial-a-ride (relative to bus transit) decrease. The positive sign of the C_{dj} coefficient indicates that the odds of an individual selecting dial-a-ride increase as dial-a-ride noncrowdedness improves. The negative sign of the R_{bj} coefficient indicates that as bus reliability increases, the odds of choosing dial-a-ride decrease. Conversely, when the reliability of dial-a-ride increases, the odds of choosing dial-a-ride increase, because the R_{dj} coefficient is positive. Finally, the positive sign of the A_{bj} coefficient indicates, as expected, that as the distance from home to bus stop increases, the odds of selecting dial-a-ride increase. Based on the likelihood ratio test (7,p.123), Equation 4b is significant at the 0.025 level. Furthermore, this equation correctly predicted 89 percent of the choices (i.e., dial-a-ride and bus transit choices) actually made by the sample.

Although the T_j variable is significant at a rather low level, the size of its coefficient is reasonable compared to similarly estimated coefficients of other studies. For example, Train (15, p.12) in a logit estimation (considering automobile, bus, and carpool as alternatives) found coefficients of -0.064, -0.026, -0.069, and -0.054 for automobile on-vehicle time, transit on-vehicle time, walk time, and transfer wait time, respectively (time was measured in minutes). In a logit estimation in a later study, Train (16,p.7), in considering automobile, bus, heavy rail, and carpool as alternatives, found coefficients of -0.047, -0.019, -0.086, and -0.048 for automobile on-vehicle time, transit on-vehicle time, walk time, and transfer wait time, respectively (time was measured in minutes).

One plausible explanation of why the travel time variable was not significant at a relatively low level of significance is the lack of sufficient variation in the data set between the travel times of dial-a-ride and bus transit services for given passenger trips. This is reasonable because the justification offered by transit management for replacing bus transit service with dial-a-ride service is often that cost is reduced rather than that travel time of passenger service is reduced. For example, dial-a-ride service is often provided with nonunion labor, which is less costly than the labor used to provide bus transit service.

In addition to the specification of Equation 4b, other specifications (i.e., considering various combinations of explanatory variables) of the logit model for work trips were considered. The specification that gave the best results in terms of improved levels of significance is the specification represented by the second equation in Table 1. All coefficients of this equation have the expected signs. The R_{dj} variable is significant at the 0.10 level of significance; the R_{bj} variable is significant at the 0.05 level of significance; and the A_{bj} variable is significant at the 0.025 level of significance. Based on the likelihood ratio test, the second equation is significant at the 0.025 level. Also, the equation correctly predicted 86 percent of the choices actually made by the sample.

In addition to work trips, dial-a-ride and bus shopping trips were considered. A logit estimation using a sample of 54 shopping trips in which all explanatory variables are significant at 0.30 or lower is given in Table 2. All coefficients have the expected sign. The variables A_{bj} and R_{bj} are significant at the 0.10 level; R_{dj} is significant at the 0.20 level; and T_j is significant only at the 0.30 level of significance. Based on the likelihood ratio test, the logit equation is significant at the 0.20 level. The equation correctly predicted 76 percent of the dial-a-ride and bus transit choices actually made by the sample.

TABLE 2 Logit Estimation for Shopping Trips

Explanatory Variables	Logit Coefficients
Constant	-1.20 (-1.59)
T_j	-.0113 (-.623)
R_{bj}	-1.03 (-1.43)
R_{dj}	.751 (1.07)
A_{bj}	.034 (1.59)
LRS	6.29
AOP	76%

Note: t-coefficients are shown in parentheses, LRS = likelihood ratio statistic, and AOP = accuracy of prediction.

POLICY IMPLICATIONS

Because cutbacks in federal assistance funds to the U.S. mass transit industry are anticipated, some mass transit carriers are considering replacing mass transit services on marginal routes with less costly paratransit services. The paratransit service, dial-a-ride in particular, is being considered as a replacement for or a supplemental service to mass transit services in relatively low-density areas. Based on empirical results, transit planners should be especially concerned with passenger perception of the reliability of dial-a-ride and bus transit services and the accessibility of bus transit in developing dial-a-ride and bus transit services. Of the number of explanatory variables considered in explaining choice of dial-a-ride or bus transit services, these variables were consistently significant at relatively low levels of significance for both work and shopping trips. Specifically, the results indicate that improvement in passenger perception of the reliability of dial-a-ride service will increase the odds of an individual choosing dial-a-ride. Alternatively, it may be stated that individuals will be more likely to switch to dial-a-ride from bus transit service as their perception of the reliability of dial-a-ride service improves. This result is particularly important, because one concern in replacing bus transit service in a particular area with dial-a-ride service in whether former mass transit riders will be willing to switch to dial-a-ride. If bus transit and dial-a-ride are allowed to compete in a particular area (i.e., both services are available), these results indicate that improvements in the reliability and accessibility of bus service will decrease the odds of an individual choosing dial-a-ride.

REFERENCES

1. A.E. Weise. Reaganomics: Spelling Trouble for Transit. Mass Transit, Vol. 8, No. 10, 1981, pp. 6-9, 32.
2. A.E. Weise. New Federalism: Transit on Its Own. Mass Transit, Vol. 9, No. 3, 1982, pp. 6-8, 11, 16, 45, 47, 49.
3. W.K. Talley. Introduction to Transportation. South-Western Publishing Co., Cincinnati, Ohio, 1983.
4. R.E. Furness. The Westport, Connecticut, Integrated Transit System. U.S. Government Printing Office, Washington, D.C., 1979.
5. R.H. Menard, M. Flusberg, and L.S. Englisher. Modeling Demand-Responsive Feeder Systems in the UTPS Framework. U.S. Government Printing Office, Washington, D.C., 1978.
6. L.A. Newmann, J.A. Wojno, and R.D. Juster. Integrated Dial-a-Ride and Fixed Route Transit in Ann Arbor, Michigan. U.S. Government Printing Office, Washington, D.C., 1977.
7. T.A. Domenich and D. McFadden. Urban Travel Demand: A Behavioral Analysis. North Holland Publishing Co., Amsterdam, The Netherlands, 1975.
8. C.A. Lave. A Behavioral Approach to Modal Split Forecasting. Transportation Research, Vol. 3, No. 4, 1969, pp. 463-480.
9. D.A. Quarmby. Choice of Travel Mode for the Journey to Work. Journal of Transport Economics and Policy, Vol. 1, No. 3, 1967, pp. 273-313.
10. R.B. Weston and D.W. Gillen. Parking Location and Transit Demand. Journal of Econometrics, Vol. 8, No. 1, 1978, pp. 75-101.
11. P. Gordon, C.S. Williams, and P.M. Theobald. Intrametropolitan Travel Demand Forecasting Using an Abstract Mode Approach. Transportation Research, Vol. 13A, No. 1, 1977, pp. 39-59.
12. 1977 TELTRAN Impact Study. Institute for Social Research, University of Michigan, and Ann Arbor Transportation Authority, Ann Arbor, Mich., 1977.
13. H.E. McAllister. Elements of Business and Economics Statistics. Wiley, New York, 1975.
14. K.J. White. A General Computer Program for Econometric Methods--SHAZAM. Econometrica, Vol. 46, No. 1, 1978, pp. 239-240.
15. K.E. Train. A Comparison of the Predictive Ability of Mode Choice Models with Various Levels of Complexity. Transportation Research, Vol. 13A, 1979, pp. 11-16.
16. K.E. Train. A Structured Logit Model of Auto Ownership and Mode Choice. Review of Economic Studies, Vol. 47, No. 147, 1980, pp. 357-370.

Publication of this paper sponsored by Committee on Application of Economic Analysis to Transportation Problems.

Export Transportation Issues

PETER L. SHAW

ABSTRACT

The U.S. seaport industry is sensitive to the ways economic forces are reflected in government policy at all levels. Possible changes in exports and the balance of trade, demographic shifts, and implications of government policy all present challenges to the seaport industry. Planning to meet the challenges in both the short and the long term is discussed, and the ways the ports of Long Beach and Los Angeles, California, are facing these challenges are described in detail.

U.S. seaports have been widely recognized as the pivotal point in the land-sea export process. Some current strategic issues that affect U.S. ports and two major southern California ports are discussed. The President in the State of the Union address noted:

> One out of every five jobs in our country depends on trade. . . . So, I will propose a broader strategy in the field of international trade--one that increases the openness of our trading system and is fairer to America's farmers and workers in the world marketplace. . . . We must strengthen the

> organization of our trade agencies and make changes in our domestic laws and international trade policy to promote free trade and the increased flow of American goods, services, and investments. . . . Our trade position can also be improved by making our port system more efficient. Better, more active harbors translate into stable jobs in our coal fields, railroads, trucking industry and ports. After two years of debate, it's time for us to get together and enact a port modernization bill. Tax policy, regulatory practices and government programs all need constant reevaluation in terms of our competitiveness. Every American has a role, and a stake, in international trade (1,part I,p.A).

Addressing the importance of the nation's balance of trade position, Martin Feldstein, Chairman, Council of Economic Advisors stated:

> The position of the United States as an exporter and importer of goods in the world economy is now undergoing a dramatic change. For a quarter of a century after the second World War, the United States exported more goods each year to the rest of the world than we imported from other countries. Many experts now forecast that the trade deficit for 1983 will rise to the unprecedented level of $75 billion, about twice last year's level; and three times the level of 1981. A trade deficit of $75 billion would represent some 2.5 percent of total GNP (2,p.588).

Although the export transportation system is not the cause of the nation's trade imbalance, it may be a contributing cost factor for its product competitiveness. Given the importance of international trade to the U.S. economy and the role that intergovernmental export transportation policy may have, there is a distinct and clear federal strategic policy interest. State and local governments are beginning to share this concern.

U.S. PORT FACILITIES

The U.S. port industry is undergoing rapid change. Because it serves as a lightning rod for much of the world and the U.S. economy, it is quite sensitive to how economic forces are translated into specific public policy at the national, regional, state, and local levels of government.

As the lead transportation institution point-of-contact for responding to trade needs, the port industry is particularly subject to political and economic, urban and environmental constraints. Often, for their own survival, ports are forced to anticipate long-range demands and needs with very fast short-term responses and implementation schemes. Because of the crisis nature of much governmental response, ports are forced to respond in this mode. Consider the coal export terminal situation, for example. The demand for coal grew quite quickly within a few years and the governmental system was not prepared to respond as fast. Ports in the meantime attempted to develop facilities and found themselves first in the middle of a long morass of administrative regulations, and then in an economic recession. The combination slowed many projects. As it turned out, the cumbersome process was, by accident, healthy because it prevented many ports from investing in capital-intensive plans and projects. Most were able to put them "on hold" before losing their initial investment due to economic slowdown and disappearance of the coal market. This illustrates the whipsaw effect of the short- and long-term interrelationships.

The U.S. port industry is diverse. There are many different components and organizational forms. Relationships with public and private agencies vary too. A summary report from the U.S. Department of Transportation noted that 189 commercial seaports (excluding those on the Great Lakes) have a tremendous influence on the national economy (3). In 1980 these 189 U.S. ports

1. Handled more than 2 billion short tons of trade,
2. Added $5.5 billion from customs fees to the treasury,
3. Contributed more than $35 billion to the gross national product,
4. Added more than $1.5 billion to the balance-of-payment accounts,
5. Generated $66 billion in direct and indirect income from gross sales and services to users,
6. Provided directly and indirectly 1 million jobs generating $23 billion in personal income,
7. Generated federal income taxes of $10 billion and state and local taxes of $5 billion, and
8. Invested more than $5 billion from 1946 to 1980 in capital facilities and anticipated an additional $5 billion through 1990.

Inland ports anticipated a $4.8 billion investment through 1990. Several other aspects of the U.S. port system should be noted:

1. Of the berths in the nation, 42.2 percent are in port city population zones of 500,000 or more;
2. Of the berths in the nation, 28.6 percent are in port city population zones of 100,000 to 499,999;
3. The physical condition of the ports is acceptable--58 percent of the national average is "good" and 29 percent of the national average is "fair";
4. Between 1970 and 1976 the industry invested $138,689,000 in federally mandated environmental protection (70 percent); employee health and safety (11 percent), and cargo security (19 percent); and
5. Between 1970 and 1976 the industry incurred $55,121,000 in operating costs for environmental protection (22 percent), employee health and safety (11 percent), and cargo security (67 percent).

It is not surprising that most of the capacity is in already developed urban areas. What is of potential concern is that, should these facilities require upgrading, modernization, or expansion, there simply may not be sufficient land surface area. Some ports have had to create new acreage from their dredge material. Another aspect of this is the potential expansion of freight movement to and from the harbors through densely populated areas. More and more conflicts with competing public purpose policies are bound to occur. At some point, local jurisdictions may face the hard decision: Should our port remain at its current level of activity with its known impacts, or should it be allowed to increase activity significantly and have possibly commensurate urban impacts?

In 1981 the ports transported 888,444,000 net tons valued at $319,255,000,000. The leading tonnage was handled by New Orleans; however, the highest cargo value was through New York. The 1982 year presented a "dismal picture." The national total dropped to 787,138,500 tons (4,p.5).

The coastal and inland ports of the United States represent a major economic and transportation activity. Their role and influence, collectively, are tremendous. Yet, politically, the governmental system responds in a fragmented way, which in part represents the nature of the port and transportation industry. Even on key issues that cut across the lifeblood of port activities (e.g., the capacity of their facilities to handle large-size vessels and channel and harbor dredging) disagreement exists. The free enterprise attitude and the realities of competitive pricing directly affect port income sources. Pressures from local and state agencies or private operators to raise or lower charges illustrate the difficulty. Reaching a common position, which is good for the whole industry, on such matters is a complex process.

PORTS AND TRADE

Export trade could be considerably larger than current levels. An opportunity exists and the United States is in a position to realize that potential. But until national policies and world economic directions are charted, ports may remain cautious. strategic port planners and transportation companies prefer to be prudent. Commitments for large new export projects have been suspended or cancelled until more confidence exists about the future of such projects. In any case, the export potential exists, if the United States sells what the world wants to buy not what the United States produces. Export sales are dependent on meeting a well-defined market need and satisfying it. They should not be driven by the reverse, that is, selling excess production designed for domestic market consumption. The switch in philosophy is basic and has not yet occurred. Port operators know the strategic planning difference. The evidence is that U.S. industry still does not.

Merchandise trade has shown a consistent deficit of more than $40 billion since 1977. The 1983 trade deficit was $69.39 billion with more than $100 billion anticipated in 1984 (5,p.7). Agricultural trade was showing a healthy surplus through 1981 but has declined with the world recession. The trade composition of the 1981 balances illustrates that the country has positive positions for capital goods, food and beverages, and industrial supplies.

Overall, the U.S. share of world exports has declined from 15.4 percent in 1970 to 13.0 percent in 1981. Since 1980 almost all merchandise categories have worsened. The data demonstrate the severe degree to which U.S. industry and agriculture have been affected by the world recession and the loss of American trade leadership. Many factors account for these problems; however, a new one is now in play. The dollar has grown stronger--so much so that foreign buyers cannot afford to purchase in dollars. Yet, stronger dollars encourage American purchasing abroad and thus more imports. Some officials believe that the dollar must weaken. The situation is "temporary" (6).

Nevertheless, demand is there. The United Nations' 1979 projections for the world population are between 5.8 billion and 6.5 billion people by the year 2000 (7,p.1). Almost 52 percent of the growth will be in less-developed countries.

Even with the huge potential world need it is quite difficult to identify demand for U.S. products by the year 2000. If the nation actively markets export opportunities, its share may be much larger than it is at present.

By 1990 cargo exports for the nation are projected at 421,800,000 long tons compared with 285,558,000 long tons in 1980. This represents a 47 percent increase (3,p.44). To meet the combined export and import cargo growth, the equivalent of 247 new port facilities will be needed by 1990, including 27 additional breakbulk handling facilities, 25 additional other bulk berths, 22 new petroleum berths, 6 new liquefied natural gas (LNG) facilities, and 19 new berths for handling other liquid bulk cargoes. The most urgent requirements for added container handling capacity in the 1980-1990 forecast period are expected to be concentrated in ports of the South Pacific, North Pacific, and North Atlantic coastal regions. The greatest need by 1990 for new or expanded breakbulk facilities is expected to occur in port areas on the Atlantic and Gulf coasts. It is anticipated that ports in the Gulf and the Great Lakes regions will experience the greatest need for added grain-handling facilities in 1985-1990. The most significant need by 1990 for new and expanded dry bulk-handling facilities is expected to be experienced in the Gulf and Great Lakes region ports.

During the 1980s, no significant changes are anticipated in cargo handling or shipping technology that would influence seaport terminal capabilities. Present trends toward increased ship size are expected to continue.

Ports are already responding to the anticipated need for additional facilities. But the plans and projects in many locations have been slowed, as illustrated by the situation of coal exports. In 1981 coal exports were at an all-time high of 110 million tons. By 1982 they had dropped to 105 million tons and the rate of decline was increasing in 1983. On the other hand, most ports have excess coal-handling capacity now (8). Just this one experience is enough to make policy makers and planners cautious.

In trying to take into account all the uncertainties discussed here, one additional factor must be added. The productive capacity and population centers of the United States are shifting to the sunbelt sections of the country. Should this trend continue, port capacity may be "out-of-sync" with locations of production and seaport shipment abroad. Pacific Rim trade potential, for example, initially may be more easily served by ports on the West Coast. Gulf and eastern ports may lose export business in some cargoes because it may become cheaper and faster to ship by rail, pipeline, or truck to the West Coast than through the Panama Canal or around South America or Africa. Similarly, should African and Middle Eastern trade grow, East and Gulf Coast ports might experience the same advantage.

STRATEGIC POLICY ISSUES

How sensitive is the export transportation system to changes in the external operating environment, the U.S. economy, and the world economy? Is the domestic and export transportation system structured for a different set of underlying assumptions than may be operating now and will be operating in the future? The systems' predicament is becoming profound. There are serious implications for management throughout government and for the port and land transportation industries that are concerned about export transportation viability. The restructuring may also provide opportunities.

Some of the external shifts now developing are

1. The domestic transportation system is predicated on an industrial structure designed for heavy industry and manufacture and natural resource and agricultural production and distribution.

2. That structure relied heavily on railroad transport and physical labor.

3. For exports and imports the system relied on a generally balanced two-way flow.

4. The international trade system was co-mingled with an extensive domestic transport infrastructure of railroads, highways, barges, and pipelines.

5. Based on international trade flows and domestic population shifts, the demand for this transportation infrastructure has shifted.

6. The older parts of the system, Northeast and Midwest, reflected the industrialized snowbelt of the country.

7. The newer parts reflected the growth in the sunbelt, South, Southwest, and Northwest, and relied more on a new extensive highway system than on railroads, except for long intercity distances.

8. The newer port facilities were also constructed in the growing South, Southwest, and Northwest.

9. Subsequent trade flows show that the greatest growth has been in exports to the Pacific Rim and not Latin America, Europe, or Africa (though needs exist).

10. Ports exporting industrialized goods and commodities will be hurt by the failure or disintegration of these industries.

There are certainly many other factors involved in this cycle, but the external forces operating appear to suggest this direction.

An early warning system might well indicate that our transport system may be located in the wrong places, has outdated technology and high costs, and is greatly subject to one-way flows with empty vehicles or containers returning to their point of origin. For some, this may seem like a roller coaster with many cyclical ups and downs happening unpredictably. Others may see these patterns and begin to suggest that it is no longer a roller coaster, it is in reality a long-term radical change. The process by which our transport system moves from older assumptions to the newer, only partly understood, assumptions will be a wrenching and difficult one. Ports and the land transport system for export will not be exempt from this and will experience many of these disconcerting effects.

SOUTHERN CALIFORNIA PORTS

For the ports of Long Beach and Los Angeles, four special issues of concern are presented.

Larger ship sizes provide a potential economy of scale that is hard to resist. Few ports in the nation are able to handle drafts of more than 51 ft. Most that can are on the Pacific Coast. Dredging is essential to maintain existing depths and capability to handle larger ships approaching the 200,000 to 250,000 ton range. Long Beach already has depths of up to 70 ft, due in large part to oil extraction and subsurface subsidence. Los Angeles is dredging now to 51 ft with federal and port funds. Permitting and fund delays increased the project cost almost three times from 1975 to 1979. Though first proposed in 1965, actual work did not begin until 1980. Though not reassuring, such time spans conform to national averages. A good part of the delay is the U.S. Army Corps of Engineers' staged process, which requires going back to Congress each time for permission and funding to proceed to the next stage. Proposals to speed up the process will help, but lack of funding will hurt. It appears that if ports wish to dredge they will have to share the cost burden, and these monies will come from user fees, cooperative funding, taxes, and so forth. Another factor that slowed the Los Angeles port dredging was the veto of plans by several agencies. Only after exasperating negotiations and technical disagreements was it possible to agree on how to handle several critical environmental issues. The result of this facility-oriented bottleneck is that if ports cannot handle the larger ships, or if they must charge for dredging costs, they will be less competitive with ports not so affected.

Coal

Coal exports look promising for the national economy. The United States has vast deposits that are attractive to foreign buyers. However, the process of extracting, processing, and transporting coal requires new facility construction and thus large financial commitments. Owners and operators are hesitant to venture forward without long-term purchase agreements. Ports, particularly Long Beach and Los Angeles, have quickly moved toward package coal exports. Five western states have coal that may come through southern California. Bottlenecks are minesite impacts, railroad transport, regional air quality, harbor land space, local railroad and street crossings, and state and local permits. One-hundred-car trains, for example, must pass over as many as 322 street-level crossings on one route between Ogden, Utah, and the ports. About 179 of the crossings are in urban southern California. Furthermore, federal policy is changing on channel deepening, coal production and leasing, protection of western coal reserves, and railroad versus coal-slurry pipeline competition.

Grain

Grain and related crops account for almost 90 percent of U.S. agricultural exports. In recent years cyclic or seasonal demand caused stress on the transport system from farm to ship. Fewer rail rights-of-way near the farm, deteriorating state and local roads and bridges, and railroad consolidation and abandonment are of grave concern. Farmers have little choice in how they transport their product and at what cost. As world demand grows again, these facilities will be severely overloaded, insufficient rail cars will be available, and traffic jams will occur at key port rail yards. Very possibly there will be competition for rail and port facilities if coal, grain, and containers move at the same time.

Containers

Container freight is rapidly replacing breakbulk freight in many sectors. For southern California, traffic has grown at an annual rate of 184 percent (1976-1980) and is predicted to increase by 300 percent for the decade (1990). To handle the growth, both ports have joined with Southern Pacific Transportation Company to construct and operate a joint Intermodal Container Transfer Facility closer to the port complex. Current separate facilities are up to 25 miles to the north, near central Los Angeles. Principal bottlenecks occur at the existing highway, rail, transfer, and port complex system for loading, carrying, unloading, and storing containers. To the extent that export cargo greatly increases, larger and longer trailers may be desirable from the operators' point of view but not necessarily from the point of view of highway facility operators and other highway users.

ACKNOWLEDGMENTS

This paper is based on research funded by the U.S. Department of Transportation, Research and Special Program Administration, Office of University Research, and California State University, Long Beach. Colleagues associated with the research included L.S. Brandt, G. Leonard, and J. Matzer. The views presented are those of the author and not of the federal government or the University.

REFERENCES

1. R. Reagan. State of the Union Address. Los Angeles Times, Jan. 26, 1983.
2. M. Feldstein. Our Exploding Trade Deficit. National Journal, March 12, 1983.
3. National Port Assessment 1980/1990. Maritime Administration, U.S. Department of Commerce, 1980, pp. 13-27.
4. AAPA Advisory. American Association of Port Authorities, May 30, 1983.
5. A. Murray. Trade Deficit Set High in 1983 of $69.30 Billion. Wall Street Journal, Jan. 30, 1984.
6. Dollar Fever Infects the World. Business Week, June 27, 1983, pp. 90-93; A Devastating Impact on U.S. Industry. Business Week, June 27, 1983, pp. 94-97.
7. H.E. Dregne. Impact of Land Degradation on Future World Food Production. Economic Research Service, U.S. Department of Agriculture, March 1982.
8. J. Lansner. U.S. Coal Industry Sees the Bubble Burst. Los Angeles Times, June 16, 1983, part I-B, pp. 1-4.

Publication of this paper sponsored by Committee on State Role in Waterborne Transportation.