NATIONAL COOPERATIVE
HIGHWAY RESEARCH PROGRAM REPORT **342**

PRIMER ON TRANSPORTATION, PRODUCTIVITY AND ECONOMIC DEVELOPMENT

TRANSPORTATION RESEARCH BOARD
NATIONAL RESEARCH COUNCIL

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PRIMER ON TRANSPORTATION, PRODUCTIVITY AND ECONOMIC DEVELOPMENT

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Silver Spring, Maryland

RESEARCH SPONSORED BY THE AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS IN COOPERATION WITH THE FEDERAL HIGHWAY ADMINISTRATION

AREAS OF INTEREST

Planning
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Socioeconomics
(Highway Transportation, Public Transit, Rail Transportation, Air Transportation)

TRANSPORTATION RESEARCH BOARD
NATIONAL RESEARCH COUNCIL
WASHINGTON, D.C. SEPTEMBER 1991

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Systematic, well-designed research provides the most effective approach to the solution of many problems facing highway administrators and engineers. Often, highway problems are of local interest and can best be studied by highway departments individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation develops increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

In recognition of these needs, the highway administrators of the American Association of State Highway and Transportation Officials initiated in 1962 an objective national highway research program employing modern scientific techniques. This program is supported on a continuing basis by funds from participating member states of the Association and it receives the full cooperation and support of the Federal Highway Administration, United States Department of Transportation.

The Transportation Research Board of the National Research Council was requested by the Association to administer the research program because of the Board's recognized objectivity and understanding of modern research practices. The Board is uniquely suited for this purpose as: it maintains an extensive committee structure from which authorities on any highway transportation subject may be drawn; it possesses avenues of communications and cooperation with federal, state and local governmental agencies, universities, and industry; its relationship to the National Research Council is an insurance of objectivity; it maintains a full-time research correlation staff of specialists in highway transportation matters to bring the findings of research directly to those who are in a position to use them.

The program is developed on the basis of research needs identified by chief administrators of the highway and transportation departments and by committees of AASHTO. Each year, specific areas of research needs to be included in the program are proposed to the National Research Council and the Board by the American Association of State Highway and Transportation Officials. Research projects to fulfill these needs are defined by the Board, and qualified research agencies are selected from those that have submitted proposals. Administration and surveillance of research contracts are the responsibilities of the National Research Council and the Transportation Research Board.

The needs for highway research are many, and the National Cooperative Highway Research Program can make significant contributions to the solution of highway transportation problems of mutual concern to many responsible groups. The program, however, is intended to complement rather than to substitute for or duplicate other highway research programs.

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FOREWORD

By Staff
Transportation Research Board

The information in this report will be of special value to transportation officials, who are interested in the relationship between transportation and the economy, and to transportation analysts, who are interested in the economic analysis methodologies and decision rules that can be applied to future capital investments to foster continued economic growth and productivity.

The recognition of capital investment as a principal catalyst of productivity, economic growth, and improved competitiveness has led transportation decisionmakers to ask how best to identify productive transportation policies and investments. For private investment, market forces help ensure that the rate of capital formation is limited to profitable and productive levels and that individual investments make a net contribution to the nation's Gross National Product. In the public sector, where market forces are weak and objectives multifaceted, transportation executives and decision-makers must have access to special information about the potential for transportation policies and investment opportunities to stimulate productivity, economic growth and gains in the standard of living. Transportation officials also need information on the kind of transportation policies and investments that have growth-related characteristics and on the methods and procedures available to identify specific opportunities for productivity and growth through transportation policy initiatives and capital investments.

The research reported here was conducted under NCHRP Project 2-17(1), "Methodologies for Evaluating the Effects of Transportation Policies on the Economy," by Hickling Corporation, Washington, D.C., with three objectives. The first objective was to identify and describe methodologies available to analyze the relationships between transportation and the economy. Of particular interest here is the relationship between transportation investment and gains in industrial productivity and competitiveness. The second objective was to critically evaluate the methodologies and the state of knowledge resulting from their use. This objective also asked how transportation agencies use alternative methodologies from both a technical and decision-making perspective. The third objective was to develop a primer for transportation executives and decision-makers that documents what is known about the relationship between transportation and the economy and provides guidance on the use of economic analysis to identify policies and investments with the potential to foster growth and productivity.

The results of Project 2-17(1) are presented in NCHRP Report 342, "Primer on Transportation, Productivity and Economic Development." The "Technical Report--Supplement to NCHRP Report 342" is published herein as Annex B. Designed for the practicing transportation analyst, this Supplement provides the technical background for the material in Report 342. It also presents a new approach, developed under Project 2-17(1), that enables the analyst to identify and quantify the logistics-related benefits for private firms that stem from transportation investments.

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The research reported herein was performed under NCHRP Project 2-17(1) by the Hickling Corporation, Washington, D.C. Christensen and Associates and Charles River and Associates were subcontractors to Hickling.

Dr. David Lewis, Partner and Chief Economist of the Hickling Corporation, was the Principal Investigator and author of the Reports. Professor Robert M. Solow of the Massachusetts Institute of Technology acted as Special Advisor to the Project, providing oversight and review at each stage of the work. Dr. Laurits Christensen and Dr. Philip Schoech of Christensen and Associates and Dr. Gary Fauth of Charles River and Associates provided technical assistance, reviewed and commented on the Primer and made written contributions to the Technical Report.

OVERVIEW

If the living standards to which all Americans aspire are to be satisfied over the next quarter-century and beyond, the United States will need to achieve a long-run rate of growth in the Gross National Product of some 3.5 percent annually. Yet most long-term forecasts foresee no more than 2.6 percent real growth if current trends continue.

Productivity: The Key to Economic Vitality

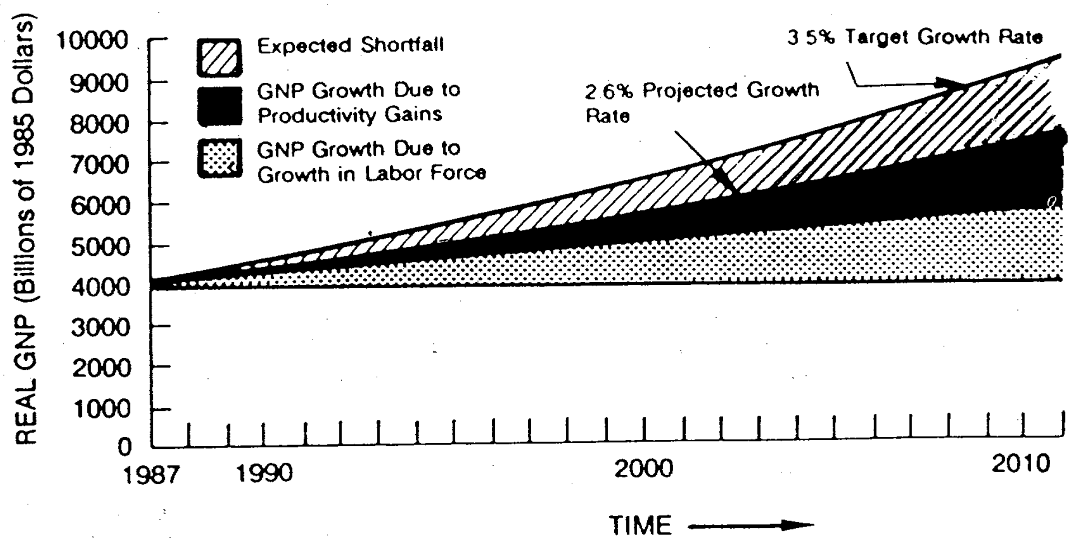
Which "current trends" need to be redirected if the nation is to pick itself up by its economic bootstraps? The Gross National Product -- the sum of all goods and services produced within domestic borders -- may be viewed as the number of workers times the output, or production, per worker. Growth in the Gross National Product will come from these two sources, growth in the labor force and growth in productivity.

The sources of growth which fueled America's 20th century rise to world prominence are changing sharply in their relative importance to future economic vitality. An aging society in particular, but also less net immigration, dictate much slower growth in the labor force in the 1990s and beyond. As a result, there is now widespread consensus that productivity growth must shoulder the nation's economic development and expansion into the 21st century. To achieve the target level of some 3.5 percent annual growth over the next 25 years, an increase in the yearly growth rate in productivity of 0.8 percent is needed. Although a 0.8 percent growth target for productivity may seem small on an annual basis, the compound effect over many years would be substantial (Overview Figure 1).

To be sure, growth in the Gross National Product is not to be regarded as a good thing regardless of its cost. Growth has implications for environmental and other living standards that are not measured by GNP and these have critical economic implications of their own. And the way in which economic expansion is shared between regions and individuals occasions independent priority. Growth for growth's sake has never been the center-piece of American public policy. Nevertheless, the fact stands that growth, through acceptable means and at acceptable costs -- "sustainable development" -- is the only means available to recover and sustain ground in American living standards, and most of the increased growth can be achieved only through increased levels of productivity.

The Key Role of Capital Investment in Promoting Productivity Growth

Whereas productivity is the key to economic growth, the rate of capital investment -- all investment, both private and public -- is key to improved productivity. It is well known that the productivity of labor depends to a large extent upon the total quantity and quality of capital per worker. The greater the capital intensity per worker, the more leverage the worker has on production. Research has documented a strong relationship between the growth rate in capital investment per worker on the one hand and the growth rate in labor productivity. Nations with high capital formation display high growth rates in labor productivity and vice versa. With the lowest growth rate in capital investment per worker among the nations of North America, Europe and Japan, the United States has also realized the lowest rate of growth in labor productivity.



SOURCE: D. Lewis, D. Hara and J. Revis, **The Role of Public Infrastructure in the 21st Century**, "A Look Ahead - Year 2020" (adapted from), R. Landau, **U.S. Economic Growth**, "Scientific American", June 1988.

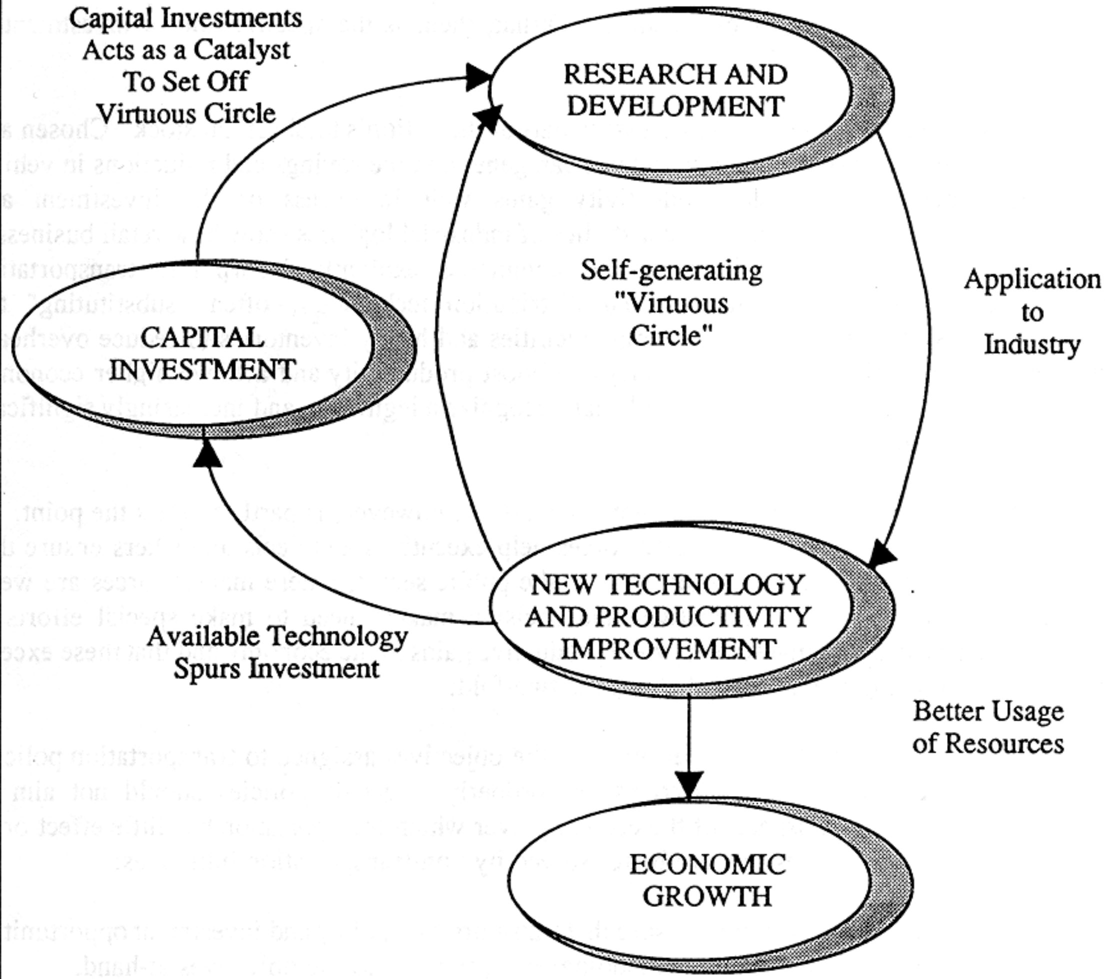
OVERVIEW FIGURE 1: PRODUCTIVITY AND LABOR CONTRIBUTIONS TO REAL GNP GROWTH

How is it that capital investment stimulates technological advance and productivity growth? According to recent economic research, the answer may be found in the way technological change is incorporated into capital equipment and facilities (see Overview Figure 2). Except for a small part devoted to basic science, research and development is seldom undertaken unless its results are expected to be applied in new facilities and superior operating modes that can improve productivity, reduce costs or raise the quality of goods and services.

Therefore, a larger rate of investment creates a market for technological improvements, spurring technological advance and improved productivity. The following quotation from the Brookings Institution Review[1] sums up the importance of capital formation to the nation's economic future:

> If the United States wants to take advantage of the robust high correlation between capital-per-worker and growth and raise real living standards, it will need to adopt stable policies favoring long-term investment. The business cycle and long-term growth must be viewed from one overall perspective. Economists may quarrel over whether growth stimulates investment or vice versa, but in practice the order is immaterial. Supply is no longer assured, even if demand is stimulated, because of the long gestation periods now required to adopt technology more efficiently. What matters is that investment in productive physical capital can promote growth, as can the proper and stable management of macroeconomic policy by the government and of individual companies by the private sector.

1 Ralf Landau, Capital Investment: Key to Competitiveness and Growth, The Brookings Review, September 1990



SOURCE: David Lewis, Daniel Hara and Joseph Revis, The Role of Public Infrastructure in the 21st Century, Special Report 220, Transportation Research Board (National Research Council), 1988.

OVERVIEW FIGURE 2: ECONOMIC GROWTH THROUGH CAPITAL INVESTMENT

The Special Role of Public Investment

There is wide-spread consensus that higher rates of capital investment are key to the future growth of productivity and living standards. What, then, is the specific role of investment in transportation infrastructure?

Public works are a fundamental and necessary part of the nation's total capital stock. Chosen and planned carefully, transportation investments can generate time savings and reductions in vehicle operating expenses that yield productivity gains well in excess of the investment and environmental costs. In addition, recent studies of industrial logistics show how retail businesses and many other sectors of industry and commerce explicitly incorporate transportation improvements into their production and distribution technology, often "substituting" the transportation system for expensive storage facilities and heavy inventories to reduce overheads and improve competitiveness. Any strategy to boost productivity and achieve higher economic growth for states and the nation as a whole can recognize a legitimate and increasingly significant role for public infrastructure.

To say that more infrastructure investment is necessary, however, is partly to miss the point. In the private sector, profit seeking market forces help executives and decision makers ensure that more investment will be good investment. In the public sector, where market forces are weak and objectives multi-faceted, executives and decision makers need to make special efforts to ensure that transportation investments yield productive gains to the economy and that these exceed the costs of achieving them. The challenge is two-fold:

- The executive must ensure that the objectives assigned to transportation policies and investment programs are properly targeted; policies should not aim to influence aspects of the economy over which transportation has little effect or to achieve aims that are better served by non-transportation initiatives; and

- The executive must ensure that transportation policy and investment opportunities are appraised with methodologies appropriate to the objectives at-hand.

Appropriate Objectives for Transportation Investment

The economic objectives of transportation policies and investments can relate to the distribution of economic activity (how the pie is shared); to growth in the volume of economic activity (the size of the pie); or to both. In general, transportation policies and investments are far more effective in promoting productivity, economic growth and improved living standards they are as instruments of redistribution.

The weight of available evidence indicates that transportation policies and investments make very little difference to total employment and income in a region. While studies often report large numbers of jobs either directly or indirectly associated with transportation facilities, more indepth investigations find that virtually all employment associated with transportation investments would be absorbed elsewhere in the labor market if the investment were not to take place. (The jobs are not "incremental"). Only where a regional economy displays long-term structural unemployment can regional net gains in employment and income stem from transportation policies and projects. Even then, the gains are typically small.

On the other hand, many transportation investments yield rates of return up to 10-times the yield on typical private sector investments. Many of these investment opportunities are long-overdue, as much as 10 years in some cases, from the viewpoint of spurring productivity and economic growth. Policies and investments aimed at reducing congestion and increasing the extent of automation in transportation systems offer especially high gains in productivity and growth. Congestion and aging technologies may thus be viewed as bottlenecks not just to traffic, but to productivity and economic growth itself. On the other hand, the impact of such projects on the distribution of regional economic activity (employment and income in particular) are very modest in relation to the overall size of regional economies, indicating a much smaller relative distributional impact.

While productivity gains alone can often justify the economic costs of transportation investments, this is rarely (if ever) the case with the employment, income and other targets of regional redistribution. Shifting the uneven distribution of economic prosperity, both nationally and among the regions and localities of individual states, has long been a priority of state and local policy makers; more often than not, state and local transportation investments claim employment impacts as their main objective. This emphasis needs to shift. If one region grows at the expense of others without generating a net addition to the sum of all economic activity, there will be no contribution to economic growth and living standards overall will stagnate and decline. Transportation executives need to emphasize productivity and growth over the redistribution of economic activity as the principal objectives of transportation policies and investment programs.

Appropriate Methodologies for Transportation Investment

From the executive's point of view, a "methodology" is simply a means of obtaining information to help guide policy and investment decisions towards the achievement of their objectives. Information is, without doubt, the decision maker's most important resource -- good information fosters good decisions while poor or inappropriate information fosters bad decisions.

Only about one-third of all transportation investment appraisals conducted over the past twenty years applied methodologies of relevance to growth in productivity, output or living standards. The remaining two-thirds produced information about the prospective redistribution of employment and income alone. Without growth-related tests, decision makers cannot discern whether or not proposed policies will yield increases in productive economic activity and living standards.

Whether growth is defined in terms of productivity, gross output or the standard of living, it can only occur if more of value is put into the economy than is taken out (spent) in order to achieve it. Only by gauging transportation policies and investments in terms of their rate of return can decision makers assess their implications for productivity and economic growth.

In assessing transportation policies, rate of return computations must embody impacts beyond those of direct consequence to the executive's responsibility area. For example, in addition to changes in the structural sufficiency of pavement expected to result from a proposed road improvement program, the highway executive needs to examine the proposal's monetary implications for vehicle operating costs and time savings, both in relation to the capital expense and future maintenance costs associated with the proposal.

As well, impacts on parties other than users of the transportation system need to be taken into account, including effects on the environment and noise. Accounting for these negative "spillovers" in "social" rate of return calculations ensures that transportation-related productivity and growth strategies are not at odds with the higher aim of improved living standards. With these modifications to the traditional rate of return principle, transportation executives can use rate of return as an index of transportation's contribution to productivity, economic growth and the standard of living. The Primer demonstrates that decision makers can be assured that policies based on social rate of return will not cause reduced economic competitiveness even where output-enhancing programs are rejected because of environmental costs. This is because such costs are ultimately, if not immediately, borne in the form of reduced efficiency and thus diminished output (see Chapter 3).

In practice, the rate of return principle should be applied to establish both *whether* a policy or investment proposal promotes productivity and growth and *when* the economically appropriate time to invest occurs.

Whether to Invest. Translating Rate of Return into Net Present Value as a Criterion of Productivity. The rate of return test permits decision makers to discern whether transportation policies and investments make a worthwhile contribution to productivity and economic growth. This requires the use of a procedure called "discounting" (see Chapter 8.0) under which the minimum-required rate of return -- such as the social opportunity cost of capital -- is used to align all forecasts of costs and benefits to a common basis of comparison. This is accomplished by computing their equivalent present-day values, a procedure designed to compensate for the fact that different policies produce costs and benefits at different rates over their service lives. The present value of the costs is then subtracted from the present value of the benefits, resulting in the *net present value.* As shown in Overview Table 1, there is a direct, simple relationship between rate of return and net present value. Although one is as good as the other in assessing a single investment proposal, net present value is the appropriate yardstick for *comparing* the economic merits of alternatives.

If the net present value of a prospective policy or investment is greater than zero, it may be considered a worthwhile contribution to productivity and well worth funding (for it means that the minimum-required rate of return is assured). The net present value criterion also permits alternative policies and investments to be ranked in order of merit. Policies and programs with higher net present values promote more productivity and growth than those with lower results. Due to certain mathematical anomalies that can arise in the use of rate of return to rank alternatives, the executive should always insist that policy and investment proposals be presented in terms of their estimated net present values.

In addition to net present value, there are other popular measures that provide interesting supplemental growth-related information for use in decision making. As shown in Overview Table 1, the "internal rate of return" indicates the *extent to which* the expected return on investment exceeds or falls short of the minimum-required rate of return and thus provides insight into project risk. The Benefit-Cost Ratio indicates the dollars of benefit generated by the policy or investment in question for each dollar cost. While these indicators provide decision makers with additional useful information, only net present value may be regarded as the basis for establishing, categorically, whether or not a prospective investment is economically worthwhile (see Overview Box 1).

OVERVIEW TABLE 1:
KEY MEASURES OF PRODUCTIVITY AND ECONOMIC GROWTH

Measure of Worth	Definition	Interpretation
Net Present Value	Present-day value of benefits minus present-day value of costs.	NPV greater than zero means project is economically efficient Projects are ranked according to NPV.
Rate of Return	The discount rate at which NPV=0	Rate of return should exceed pre-set hurdle rate to qualify for consideration.
Benefit-Cost Ratio	Present value of benefits divided by the present value of costs. Indicates dollars of benefit per $1.00 of cost.	A ratio of greater than one means the project is worthwhile.
Measures of Timing		
First-Year Benefit	Benefits in the first year after construction divided by costs to date including interest paid during construction, expressed as a percent.	A ratio equal to the hurdle rate means the project is optimally timed. A ratio below the hurdle rate means the project is premature. A ratio above the hurdle rate means the project is overdue.
Pay-Back Period	Number of years until capital recouped through the flow of benefits.	A short pay-back period means less risk.

OVERVIEW BOX 1

CASE STUDY

TRANSPORTATION, PRODUCTIVITY AND OVERDUE INVESTMENT: The Use of Rate of Return; Net Present Value; and First-Year Benefit Tests

In 1982, the Federal Aviation Administration formulated a $24 billion plan to modernize the nation's air traffic control system. Through automation, the Plan would increase capacity to handle traffic, diminish risks of mid-air collision and other hazards, and shorten flight times by allowing aircraft to follow more direct routes. Facility consolidation and staff reductions from automation would increase productivity and reduce operating and maintenance costs.

Rate of Return

On the basis of these benefit and cost projections, the CBO calculated that the annual rate of return to be expected from the FAA plan over the two decades is 24.3 percent -- a healthy return by any standard (see Summary Table). Indeed, measured against the commonly used if somewhat arbitrary standard of 10 percent set by the Office of Management and Budget (OMB) for federal investment, it was concluded that the FAA plan is likely to offer very good value.

CBO noted that another useful guide to the economic value of a capital project is the present value of the expected benefits minus the costs (net present value). Using 10 percent rate of return to adjust future costs and benefits to their present-day values, the benefits of the FAA plan were estimated to exceed its costs by $9.1 billion in net productivity gains.

	Return on Investment			**Timing**
Forecasts	Rate of Return (In percents)	Benefit-to-Cost Ratio a/	Benefits Minus Costs (In billions of dollars) *Net Present Value*	Return in the First Year after Completion (In percents)
Under FAA Assumptions	24.3	2.3:1	9.1	14.9
Under Lower Traffic Forecast Scenario	21.3	2.0:1	6.8	13.1

SOURCE: Congressional Budget Office.

a. Benefits and costs are discounted to their 1982 values at the annual rate of 10 percent.

Timing and Identification of Overdue Investments

The Congressional analysis also looked closely at the project's timing from the viewpoint of productivity and economic growth. Using the First-Year Benefit ratio, the study concluded that since the return in the first year after project completion was likely to *exceed* the minimum-required rate of return, automation of the system was actually overdue.

The recent application of this test of infrastructure investment timing to airport expansion projects at Vancouver and Minneapolis-St. Paul indicate that these investments are each more than 10 years overdue (First-Year Benefit Ratios in each case exceed 100 percent, more than ten-times the 10 percent minimum-required annual rate of return set for these investments.

In the case of the air traffic control system and that of airport expansion in Minneapolis-St. Paul, evidence about timing strongly influenced decisions to undertake large-scale investments.

Net Present Value Versus Sufficiency Ratings and Cost-Effectiveness Analysis as a Basis for Infrastructure Decision Making. Many states, localities, transportation authorities (and the federal government) use pavement sufficiency ratings, volume-to-capacity criteria and various forms of cost-effectiveness analysis to judge the merits of alternative investment policies, programs and projects. The executive thus needs to know whether these approaches will lead decision makers to the most economically productive projects.

All the evidence, both theoretical and actual experience, indicates that sufficiency ratings, volume-to-capacity criteria and cost-effectiveness tests do a poor job of helping decision makers find the most productive transportation policies and projects. Where the economic aims of transportation policies include diminished vehicle operating costs, reduced congestion and delay, enhanced safety and environmental conditions and stronger business and industrial productivity, net present value leads to different and substantially better investment decisions than sufficiency ratings or cost-effectiveness analysis.

The Highway Case. Highway sufficiency ratings -- engineering standards used to evaluate the structural, safety and level of service attributes of roadways -- are used by most states to rank construction projects. As well, the Federal Highway Administration and a number of states have devised cost-effectiveness tests as a basis for decision making. These tests are typically measured by the capital cost of a proposed improvement divided by the projected change in sufficiency rating. In some cases, the sufficiency rating is first multiplied by the annual average daily traffic over the roadway in question in order to favor the improvements of heavily travelled over lightly travelled roads. A few states use discounted life-cycle cost in forming the cost-effectiveness ratio (capital costs and plus maintenance costs expected to be incurred in each year of a project's estimated life, all expressed in the present day equivalent and then divided by the sufficiency rating).

Economic theory predicts that the benefits of roadway and network improvements will be greater (maximized, in fact) if net present value is used instead of sufficiency ratings and cost-effectiveness tests as a basis for decision. This has been confirmed in tests of actual projects. These tests show that net present value test guides decision makers to projects with significantly greater highway benefits than those arising under other criteria. This means that more vehicle cost savings, reductions in delay, safety and environmental benefits and business and industrial productivity gains will be achieved if decisions are guided by the net present value criterion as compared with the application of sufficiency ratings or cost-effectiveness tests (see Overview Box 2).

An advantage of the sufficiency rating and cost-effectiveness approaches is their broad acceptance in the highway planning community. It is clear however that the use of these approaches for investment decision making causes a major sacrifice in the economic benefits to be drawn from transportation infrastructure and in the contribution of transportation investment to productivity and economic growth. Executives should thus insist upon the availability of net present value information as part of the highway investment decision making process.

The Transit Case. The net present value criterion has also been found to be the only reliable test of economic performance in other aspects of transportation infrastructure. In theoretical tests, the London School of Economics has concluded that sizeable reductions in welfare and economic living standards can result from the use of cost-effectiveness tests in lieu of net present value

OVERVIEW BOX 2

CASE STUDY

Net Present Value versus Sufficiency Ratings and Cost-Effectiveness Analysis as a Basis for Highway Investment Decisions

The Texas Transportation Institute compared three techniques for ranking and selecting highway construction projects under a budget constraint. Benefit-Cost Analysis was used to estimate net present values for 1,942 capacity-related projects. Sufficiency ratings and cost-effectiveness tests were also developed and all projects were ranked accordingly.

The net present value criterion was found to guide decision makers to better and more economically sound highway projects than either of the other two approaches. The table below reports cumulative estimated benefits in the form of vehicle cost savings; time savings; safety and environmental benefits; and business and industrial productivity gains. For a ten-year budget of $5.7 billion, decisions based on the Net Present Value procedure yield over $22 billion more benefits than decisions based upon the sufficiency rating and some $7.8 billion more than the cost-effectiveness approach.

Cumulative Highway Improvement Benefits as Selected Budget Levels, by Decision Criterion

Ranking and Decision Criterion	Cumulative Benefits ($ Billion) for Cumulative Cost of: $0.785 Billion (One-Year Program)	$3.551 Billion (Five-Year Program)	$5.742 Billion (Ten-Year Program)
Texas Sufficiency Rating	$ 7.316	$ 24.610	$ 36.512
Texas Cost Effectiveness	12.980	39.034	51.618
Net Present Value	16.780	45.723	59.202

SOURCE: Texas Transportation Institute, 1987 maximization in transit decision making.

Tests with actual projects (see Overview Box 3) confirm that cost-effectiveness tests can deter decision makers from choosing transit projects with the highest potential contribution to productivity and economic growth.

The Airport Case. Many airport authorities use volume-to-capacity criteria to make judgements about the need for runway, taxiway, terminal, parking and other capital investment decisions. Here the evidence mirrors that of the highway and transit cases. Volume-to-capacity criteria are necessarily arbitrary, indicating nothing about whether or when newinvestment is economically worthwhile. Case studies demonstrate that volume-to-capacity tests in practice tend to understate the level of desirable investment and fail to reveal the urgency of investment opportunities from the perspective of their contribution to productivity and growth.

When to Invest. Net Present Value and the First-Year Benefit Ratio as an Index of Optimal Timing. Though critical to economic success, the right timing for policies and investments is often overlooked in transportation investment planning. Since productivity benefits, such as fuel and time savings, often increase over time as traffic levels grow, an investment that appears worthwhile overall may draw principally on distant forecasts in order to display a strong net present value. In the early years, such projects often display very poor rates of return, to be offset by stronger returns later on. The construction of Dulles International Airport near Washington DC is a case in point. Though clearly a highly productive investment, Dulles did not begin to generate reasonable returns until 15 years after its construction. In such cases, it is economically worthwhile to hold-off implementation until the rate of return is expected to achieve minimum-requirements in the nearer term, thereby liberating capital dollars for more productive policies and investments in the meantime.

Table 1, the *first-year Benefit* test provides an unambiguous check on whether the proposed timing of a policy or investment is economically sensible in terms of net present value. Executives need to be aware that the optimum year in which to commission an investment is the start-date that maximizes its net present value. Net present value can be shown to be maximized when the benefits in the first year after commissioning an investment, divided by the total costs incurred to that date (including interest), is equal to the minimum-required rate of return. If this ratio -- called the *first-year Benefit Ratio* is more than the minimum-required rate of return, it means that delaying the project would increase its net present value. On the other hand, if the first-year benefit ratio is less than the minimum-required rate of return, the policy or investment may be said to be overdue.

The application of this test to recent major transportation investment proposals in Minneapolis-St. Paul, Vancouver, British Columbia, the federal Air Traffic Control System and others indicate that a great many infrastructure investments are significantly overdue from the viewpoint of maximizing the rate of growth (both regionally and nationally) in productivity, output and living standards. Many projects display projected rates of return in their first year of operation in excess of 100 percent.

Other measures of timing -- such as the number of years an investment needs to break-even (ie, for the value of productivity gains to match the investment cost) -- provide useful information for decision makers. The faster they pay-back the less reliant the investment's return is upon

OVERVIEW BOX 3

CASE STUDY

Net Present Value versus Cost-Effectiveness Analysis as a Basis for Transit Investment Decisions

Many transit authorities, as well as the federal government, use cost-effectiveness tests to help guide investment decisions. Tests such as cost per new-rider do help in the search for investments that maximize the number of travellers attracted to transit for each dollar spent on facilities and services. Such tests do not, however, indicate which alternatives offer the highest net economic returns nor whether the economic benefits of transit projects, such as time savings and environmental gains, outweigh their costs and thus contribute to productivity and economic growth.

Tests conducted in preparing the Primer confirm that cost-effectiveness and net present value tests can yield very different economic signals to decision makers. The Case Study reported in the Table below indicates that, for the city in question, the cost-effectiveness test favors a light rail option whereas the net present value criterion indicates that an express bus approach is likely to yield a higher net economic benefit.

The Table also indicates a risk that none of the options considered are likely to yield benefits in excess of costs (all net present values being negative). This information would be unavailable with only cost-effectiveness information.

Like any forecast, however, net present values should be viewed in the context of sensitivity and risk analysis. Express Bus Option Two, for example, produces an NPV near zero, indicating a broadly satisfactory rate of return. As well, a longer assumed life for each of the options shows that the Light Rail Two alternative is likely to yield a positive Net Present Value. The Express Bus Option Two, however, remains the most economically attractive from an economic perspective.

Economic Benefits of Alternative Transit Improvements in a Selected Urban Area, by Alternative Decision Criteria

Alternative	Cost-Effectiveness (Cost Per New Rider)	Net Present Value (Millions)
Transportation System Management	$ 3.71	-$ 5.60
Express Bus Option One	$18.18	-$16.40
Express Bus Option Two	$ 3.12	-$ 0.30
Light Rail Option One	$ 5.86	-$46.90
Light Rail Option Two	$ 2.87	-$ 8.60

relatively distant and uncertain forecasts. The is obviously an attractive trait of any prospective investment but, again, optimality requires the maximization of net present value.

Returns Associated with Industry Restructuring and Network Economies

In appraising the rate of return of many prospective transportation policy and investment possibilities it is sufficient to estimate the savings in vehicle operating costs and the value of time savings as the principal investment benefits. It is now understood however that this will only be sufficient when there is no significant change in the production processes and logistics of firms in response to the investment.

Where changes in production logistics can be expected, however, the conventional yardstick of "user-benefit" fails to measure all significant economic benefits. This raises the concern that the sum of all infrastructure projects approved according to conventional approaches to rate of return and net present value maximization will fail to achieve the level and mix of transportation investments that maximizes transportation's contribution to productivity, economic growth and living standards.

It is possible, for example, that major network improvements can lead firms to substantially restructure their logistics and distribution networks. This is because reduced congestion throughout a network improves the reliability of delivery schedules so that smaller and more frequent deliveries are made; this in-turn facilitates reduced inventory, handling and packaging costs. As shown in Overview Box 4, firms may also eliminate distribution centers, clustering fewer depots around key points in the improved transportation network. Case studies suggest that failure to account for such network economies can lead to a substantial understatement of the prospective impacts of transportation investment on productivity and economic growth.

The Primer provides a newly developed technique, called Industrial Restructuring Analysis, to help measure and quantify these impacts. Such techniques, and the questions they address, are in their infancy and executives need to approach them with care. An awareness of the question, however, should open up productive new lines of reserch.

Investment Appraisal, Living Standards and Sustainable Development

Infrastructure projects are often delayed, sometimes indefinitely, because of local environmental concerns. To be sure, transportation investments can create measurable environmental costs; but new methods of evaluation also reveal that the economic benefits are often far larger still, large enough in fact to cover environmental mitigation costs (insulating homes against highway or aircraft noise, or replacing wildlife habitat, for example) while still earning a strong economic return. Yet this "sustainable development" aspect of transportation infrastructure is rarely conveyed to the public through the investment appraisal process. Nor do typical appraisals include mitigation and compensation programs within the range of alternatives and implementation plans considered. As pressures mount for environmentally stable public investment planning, executives will need to present investment plans that demonstrate their scope to generate economic gains that are sufficient to cover the costs of mitigation.

OVERVIEW BOX 4

CASE STUDY

Accounting for Industrial Productivity Benefits Associated with Major Network Improvements

Sainsbury's, Britains largest supermarket chain, considered the impact of a road network improvement on food distribution. The road improvements are seen to have two impacts. One is to reduce the driving time required for trips. The second, as a result of the faster driving time, is to permit the firm to make a major structural change in logistics, namely to reduce the number of its depots from 6 to 5. The closure of depots requires an increase in the number of miles travelled of 9.5%, but the additional cost is outweighed by the savings from closing a depot. Savings in closing the depot come from reduced inventory holdings and economies of scale in handling increased volumes of goods with one less depot.

The firm looked at the measurement of benefits in two ways. Case A, counts only the savings in driving time and associated costs, assuming that the structure of the firm's operations remains the same. Case B, considers the additional impact from the reduction in the number of depots.

Savings from Improvements in Road Network

	Per case handled
	British Pence (p)
Case A	
- Transport savings without restructuring	1.3
Case B	
- With Restructuring	
Marginal volume benefit	1.6
Stock saving	0.5
	2.1
Less extra transport cost	0.5
Total	1.6
- *Extra benefit* over transport savings	0.3 over 1.3p=23%

The analysis indicates that true benefits to the firm, including the benefits of restructuring, are 23 percent higher than those captured by conventional Benefit-Cost practice which would measure only the direct benefits from faster travel time.

Formal theoretical extensions of the traditional Benefit-Cost framework developed for the Primer confirm the validity of the Sainsbury's analysis (see Technical Report). Other tests conducted in the Technical Report indicate that failure to account for productivity impacts can understate the true economic of major improvements by more than 100 percent.

The Executive's Good-Practice Check List

Although executives are in the hands of technical experts for the correct application of techniques and procedures, careful inquiry at periodic intervals throughout the evaluation process can ensure sound results. As every good manager knows, monitoring and challenging technical assumptions is critically important. It is also critical for executives to monitor and ask questions about seven key methodological attributes of any economic evaluation of transportation policies and investments, as follows:

- **Objectives.** Executives should insist that investment objectives be displayed first in terms of productivity, growth and living standards and secondarily in terms of distributional and other objectives. This promotes the search for productive transportation investments while still exposing opportunities to influence employment levels and other redistributional aims (Chapter 2).

- **Methodology.** Methods of investment appraisal should emphasize rate of return and net present value techniques. Assessments of the regional employment, income and output implications of policy and investment proposals need to be expressed as differences from the "without" investment case (ie, incrementally) in order to draw valid conclusions regarding distributional implications (Chapter 3).

- **The Base Case.** It is rarely adequate to treat the status quo as the basis of comparison for major investment proposals. Steps, including congestion pricing, to redress existing problems without the need for major capital investments can liberate scarce capital resources for even more productive transportation uses. The Base Case should represent, as closely as possible, the most efficient and productive use of existing assets, even if expenditures are required to achieve it (Chapter 4);

- **Benefits.** All benefits should be identified. Where major network improvements are contemplated (in all modes), benefits associated with industry restructuring and related logistics and productivity gains should be explored to the extent feasible (Chapter 6);

- **Costs.** All costs should be included in the economic appraisal, not just those to be financed from state and local resources. As well, all environmental costs should, to the fullest possible extent, be quantified and incorporated in the rate of return and net present value calculations (Chapter 7);

- **Discounting.** All benefits and costs must be projected over the expected service life of the *longest-lived option under review* and expressed in terms of their present-day values using the technique of discounting. Failure on either count can lead to very poor economic choices such as policies favoring annual pot-hole repair over long-term pavement reconstruction (Chapter 8);

- **Risk and Public Involvement.** The economic evaluation of public investments involves judgements, forecasts and assumptions, all of which are uncertain and subject to public controversy. Appraisals should be conducted with public involvement; they should expose all risk and uncertainty and quantify the implications for decision making to the fullest extent feasible (Chapter 9).

CHAPTER 1

INTRODUCTION

The reassertion of U.S. global economic leadership is fundamental if the living standards to which all Americans aspire are to be satisfied over the next quarter-century and beyond. In light of the economic prospects for the nation's major competitors, the United States needs to achieve a long-run rate of growth in the Gross National Product of some 3.5 percent annually just to sustain current living standards, which, by most conventional yardsticks, have already declined since the 1960s in terms of real purchasing power. The Bureau of Labor Statistics records that average real earnings in 1989 had fallen to the level of 1961. Yet most long-term forecasts foresee no more than 2.6 percent real growth if current trends continue.

THE SOURCES OF FUTURE ECONOMIC GROWTH: MORE WORKERS OR MORE WORKER PRODUCTIVITY?

Which "current trends" need to be redirected if the nation is to pick itself up by its economic bootstraps? The Gross National Product -- the sum of all goods and services produced within domestic borders -- may be viewed as the number of workers times the output, or production, per worker. Growth in the Gross National Product will come from these two sources alone, growth in the labor force and growth in productivity.

The factors which fuelled America's 20th century rise to world prominence are changing sharply in their relative importance to future economic vitality. The demographic facts of life, an aging society in particular, but also less net immigration, dictate much slower growth in the labor force in the 1990s and beyond. As a result, there is now widespread consensus that productivity growth must shoulder the nation's economic development and expansion into the 21st century.[1] To achieve the target level of some 3.5 percent annual growth over the next 25 years, an increase in the yearly growth rate in productivity of 0.8 percent is needed. Although a 0.8 percent growth target for productivity may seem small on an annual basis, the compound effect over many years would be substantial (Figure 1).[2]

To be sure, growth in the Gross National Product is not to be regarded as a good thing regardless of its cost. The environmental consequences of growth have critical economic implications of their own. And they way in which economic expansion is shared between states and individuals occasions independent priority. Growth for growth's sake has never been the center-piece of American public policy. Nevertheless, the fact stands that growth, through acceptable means and at acceptable costs -- sustainable development -- is the only means available to recover and sustain ground in American living standards, and most of the increased growth can be achieved only through increased levels of productivity.

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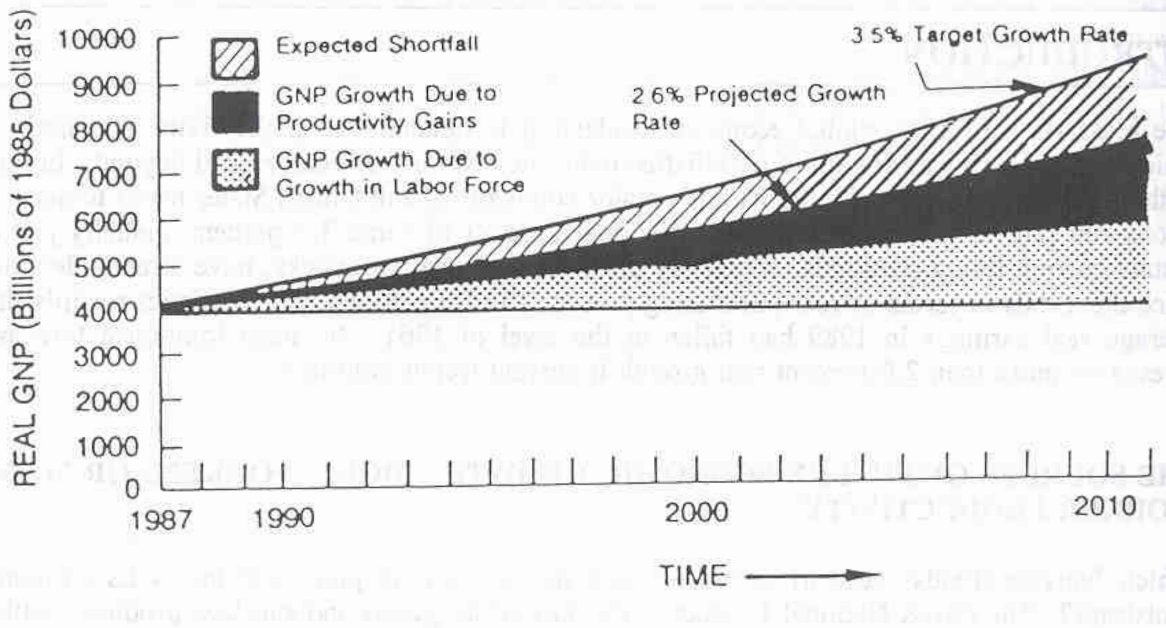
1 It is interesting to note that studies of Professors Robert Solow, Laurits Christensen and Dale Jorgenson have attributed up to 85 percent of America's growth in the 20th century to productivity increases as distinct from increases in the size of the labor force.

2 David Lewis, Daniel Hara and Joseph Revis, **The Role of Public Infrastructure in the 21st Century,** Special Report 220, Transportation Research Board, 1988.



SOURCE: D. Lewis, D. Hara and J. Revis, The Role of Public Infrastructure in the 21st Century, "A Look Ahead - Year 2020" (adapted from), R. Landau, U.S. Economic Growth, "Scientific American", June 1988.

FIGURE 1: PRODUCTIVITY AND LABOR CONTRIBUTIONS TO REAL GNP GROWTH

THE KEY ROLE OF CAPITAL INVESTMENT IN PROMOTING PRODUCTIVITY GROWTH

Whereas productivity is the key to economic growth, the rate of capital investment -- all investment, both private and public -- is key to improved productivity. It is well known that the productivity of labor depends to a large extent upon the total quantity and quality of capital per worker. The greater the capital intensity per worker, the more leverage the worker has on production. Research has documented a strong statistical relationship between the growth rate in capital investment per worker on the one hand and the growth rate in labor productivity. Nations with high gross capital formation display high growth rates in labor productivity and vice versa. With the lowest growth rate in capital investment per worker among the nations of North America, Europe and Japan, the United States has also experienced the lowest rate of growth in labor productivity.

Of special importance is the effect of the rate of capital investment on the productivity of capital. Because new capital tends to embody the latest technology, the more rapidly new capital is added to the capital stock, the faster average productivity will grow. Significantly, the rate of technological progress is itself dependent upon the rate of capital investment. The more quickly new capital is added to the capital stock, the better the quality of that capital will be in terms of the innovative technology it embodies.[33] This in turn means higher productivity and higher growth.

How is it that capital investment stimulates technological advance and productivity growth? According to recent economic research,[4] the answer may be found in the way technological change is incorporated into capital equipment and facilities (see Figure 2). Except for a small part devoted to basic science, research and development is seldom undertaken unless its results are expected to be applied in new facilities and superior operating modes that can improve productivity, reduce costs or raise the quality of goods and services. Therefore, a larger rate of investment creates a market for technological improvements, spurring technological advance and improved productivity.

THE SPECIAL ROLE OF PUBLIC INVESTMENT

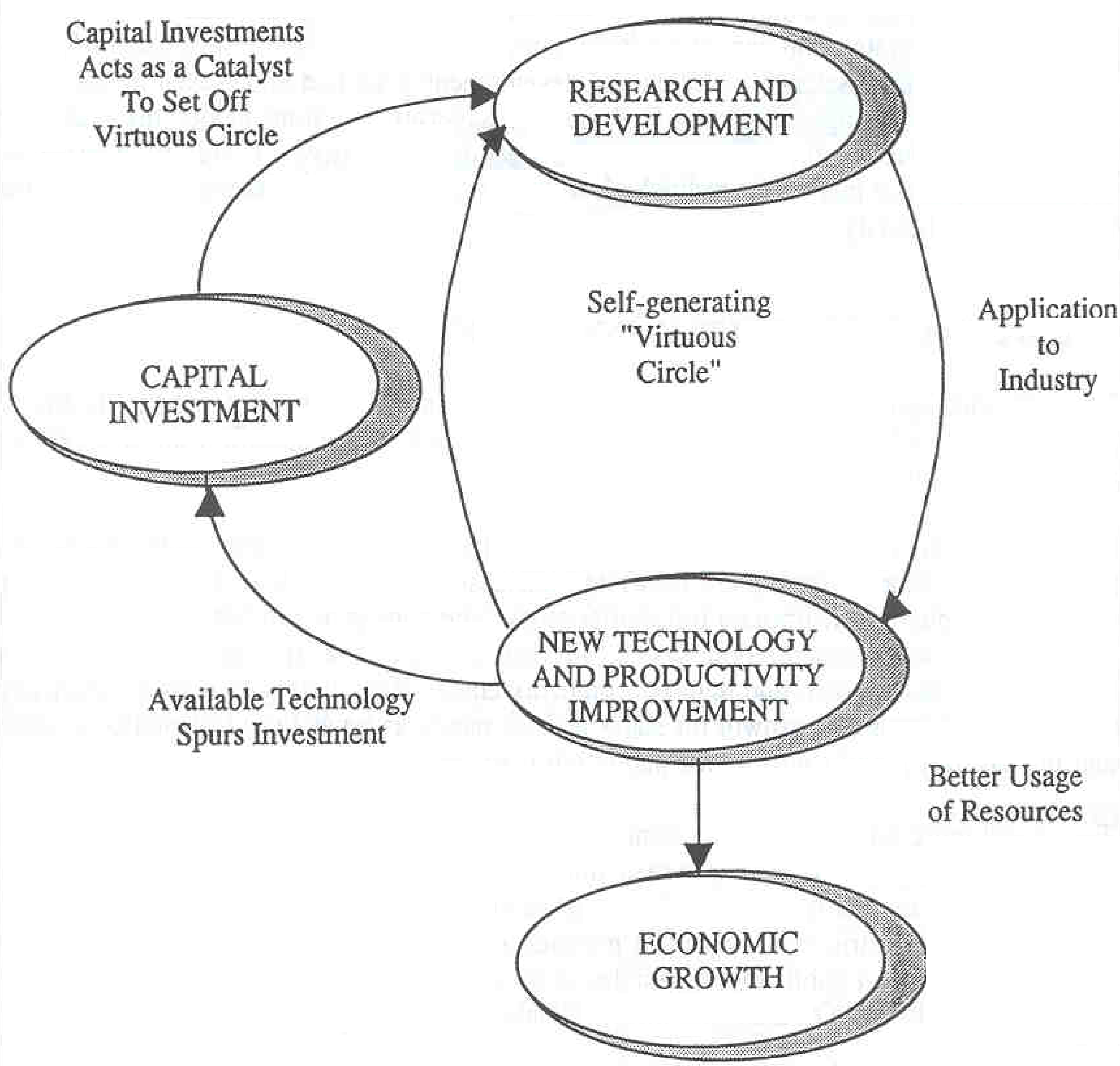
There is wide-spread agreement that higher rates of capital investment are key to the future growth of productivity and living standards. What, then, is the specific role of investment in transportation infrastructure in particular?

Public works are a fundamental and necessary part of the nation's total capital stock. Recent studies of industrial logistics show how retail businesses and many other sectors of industry and commerce explicitly incorporate transportation systems into their production technology, often "substituting" the transportation system in lieu of expensive storage facilities and heavy inventories to reduce costs and improve competitiveness. Any strategy to boost productivity and achieve higher economic growth for states and the nation as a whole can recognize a legitimate and increasingly significant role for public infrastructure.

To say that more infrastructure investment is necessary, however, is partly to miss the point. In the private sector, profit seeking market forces will ensure that more investment will be good investment. In the public sector, where market forces are weak, special efforts must be made to ensure that infrastructure investment matches and enhances productivity gains in the private sector. Because most public investment decisions are made at the state and local level, this raises the question of the role of state and local officials in the public investment process.

3 An obvious example here is the rate of capital investment in computers and advanced automation; the more quickly U.S. corporations adopt modernized computer technology, the faster they can innovate and reap productivity gains. A less obvious example is the rate of capital investment in highway network improvements. Since "just-in-time" inventory technology effectively embodies modernized highway design and traffic control, an effective network improvement program can lead firms to adopt more productive inventory systems; clearly, the more rapidly the network improvements occur, the more rapid the pace of inventory productivity will be.

4 Ralf Landau, U.S. Economic Growth, Brookings Institution Review, August 1990 (See also Landau, Scientific American) June 1988.



SOURCE: David Lewis, Daniel Hara and Joseph Revis, **The Role of Public Infrastructure in the 21st Century**, Special Report 220, Transportation Research Board (National Research Council), 1988.

FIGURE 2: ECONOMIC GROWTH THROUGH CAPITAL INVESTMENT

CAPITAL INVESTMENT, PRODUCTIVITY AND THE ROLE OF STATES AND LOCALITIES

One of the most important national objectives associated with economic development is to narrow differences in the economic welfare of regions. Moreover, states and localities naturally compete and seek policies and investments, including transportation investments, that attract resources, employment and economic activity. In the case of transportation infrastructure, however, such investments often require large capital expenditures and on-going maintenance and operating outlays. Unless these investments yield economic gains, including productivity gains, that exceed the costs of achieving them, they will make no contribution to the nation's overall rate of economic expansion. Interregional competition, like competition generally, is a healthy thing. But when a region grows at the expense of others without generating a net contribution to the sum of all economic activity, living standards for all will stagnate and decline over the long-term.

MAKING GOOD INVESTMENT DECISIONS AT THE STATE LEVEL

To ensure that capital investments trigger economic growth and enhanced productivity, there needs to be a complementary relationship between the quantity of capital investment and the quality of that investment. In the realm of public investment, a deliberate effort on the part of state and local executives and decision makers is necessary to seek out those infrastructure policies, programs and projects that, in addition to their success in attracting economic activity to the region, offer scope for enhanced growth and productivity. To succeed, decision-makers must be assured of three fundamental requirements:

- The objectives of infrastructure policy, program and project alternatives must recognize productivity and growth as desired outcomes and appropriate evaluation methodologies must be selected accordingly;

- Methodologies must be applied properly and accurately; and

- To the fullest practical extent, the business and industrial productivity implications of public investment alternatives should be identified.

PLAN OF THE PRIMER: A STRATEGY OF DECISION

This primer is intended to assist transportation executives and the decision makers they serve in ensuring that transportation policies and investments promote not only regional gains but enhanced economic growth as well. "Executives" are the senior managers in state and local transportation departments, commissions and authorities who are accountable for the quality of the information available to decision makers. "Decision makers" are those who are accountable to the public for the quality of decisions themselves. Executives and decision makers are at times one and the same individual and at times they are not.

While this is not a technical manual -- indeed, even technical language is minimized throughout -- it does serve as a guide for decision makers and analysts alike in the correct choice of an evaluation strategy in relation to the desired objectives of the transportation policies, programs and projects under review. And it serves as a guide to the faithful execution of key methodological principles. Both are necessary in the pursuit of transportation policies that form part of an economic strategy of enhanced competitiveness and a growing standard of living.

Each Chapter of the Primer focuses upon a distinct and pivotal aspect of the investment decision process and each is presented in four separate sections that, taken together, provide a "strategy of decision" for each aspect of the process. The four sections are:

- Primer on Strategic Principles;
- Primer on Procedures and Techniques;
- Primer on Good Practice and Common Errors; and
- Primer on Technical Language and its Interpretation.

The strategy of decision involves the executive throughout the process of establishing objectives and alternatives, evaluating the choices and establishing policies and programs. Mindful of the limited amount of time available to the executive for such activities, each of the above four sections provides targeted approaches for decision maker involvement and lists the questions executives need to direct to project analysts and proponents throughout the process in order to ensure well conceived strategies and decisions.

OUTLINE OF THE PRIMER

The Primer is presented in two Parts. Part I, consisting of Chapters 2 and 3, provides an overview of the role of transportation in the economy. Chapter 2 offers guidance for decision makers in the choice of appropriate economic objectives for transportation policies, programs and projects. The chapter includes a broad review of the evidence with regard to the effectiveness of transportation policies in stimulating productivity, economic growth and the redistribution of economic activity between regions. Chapter 3 then presents a framework for ensuring an appropriate evaluation and methodological strategy in light of the selected objectives. Evidence is reviewed with regard to the appropriate role of alternative methodologies in measuring the implications of transportation policy.

Part II, Chapters 4 and 5, offers decision making strategies for the development of policy alternatives. Chapter 4 focuses on the critical need to devise an appropriate Base Case, one that ensures the most productive and efficient use of existing assets as a baseline against which alternatives are to be evaluated. Chapter 5 provides guidance on the design and specification of alternatives to the Base Case.

Transportation infrastructure policies involve both substantial economic costs as well as the potential to enhance productivity, growth and regional economic performance. Both, moreover, occur over long periods of time which also affects the actual value of economic impacts. Part II, Chapters 6 and 7 provide the decision maker with guidance on assessing costs and impacts. Chapters 8 and 9 follow with strategies for decision makers in their examination of trade-offs between costs and impacts in the context of their economic objectives. Chapter 8 provides guidance on the proper treatment of inflation and the time related value of costs and impacts. Chapter 9 then provides strategies for comparing costs and impacts as a basis for decision including effective methods of dealing with risk and uncertainty.

Annex A briefly introduces the newly developed procedure (covered in greater detail in Part III of the Technical Report), called "Industrial Restructuring Analysis: Exploring and Measuring Industry-Related Productivity Impacts of Transportation Policies." The Primer refers to the Technical Report, a compendium of research conducted in its preparation. This Primer also refers to the 1990 Survey of Current Practice, which was conducted as part of the Primer's development to ascertain current approaches and to assess problems and issues in the field. For the benefit of those interested in the subject, the Technical Report Supplement is published herein as Annex B.

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PART I

TRANSPORTATION

AND

THE ECONOMY

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ALTERNATIVE ECONOMIC OBJECTIVES AND EVIDENCE OF THEIR ACHIEVEMENT

Many state and local officials remember the professional exhilaration and inspiration that characterized transportation planning in the early days of the Interstate Highway System. The economic mission was noble and clear, its merit beyond doubt and the likelihood of its achievement virtually undeniable. The knowledge that national economic growth would be fostered by a system of interregional highways and that virtually all states would benefit constituted the political glue that bonded competing regional interests to the common goal of completing the system. As well, those involved in developing the nation's airports and other major infrastructure systems also recall a vision of combined regional and national economic purpose.

Today the major national transportation systems are in place and the number of capital programs and projects with an obvious "nation-building" component has diminished. Transportation objectives at the state and local level tend to reflect regional interests; while this is as it should be, a parallel sense of national economic purpose has largely eroded. The 1990 Survey of Current Practice finds that policy decisions rest largely on the ability of transportation to attract employment and related economic activity to a region with little or no emphasis on the net contribution to economic growth.

PRODUCTIVITY AND ECONOMIC GROWTH: THE NEW VISION IN TRANSPORTATION PLANNING

As in the past, state and local transportation executives need to serve the regional economic priorities of their constituents. But is there a common economic vision of transportation planning that states and localities need to share in shaping the foundations of life in the 21st century? What constitutes the interregional political glue of transportation decision making now?

Though not quite so tangible as completion of an interregional highway network or air traffic control system, the unifying interest of transportation planning today is as compelling and urgent as it was in the 1950s. The collapse in productivity growth which took root in the mid-1970s creates what is perhaps the greatest risk to the standard of living in every state and locality. Productivity growth, on the other hand, offers abundant rewards, allowing industry to maintain and increase real wage levels while remaining cost competitive with foreign industry.

Capital investment, including the development and maintenance of transportation infrastructure, offers one of most effective known catalysts of productivity growth. Economists are in broad agreement that a lack of investment not only causes a loss of productive capacity in its own right but also hurts the value of investments already made. Transportation investment, and network improvements in particular, can trigger technological innovation in private firms, with important economic gains that extend beyond those previously associated with infrastructure development.

Clearly, transportation infrastructure executives, like other (public and private) managers of capital investment, are truly in control of one the best hopes for U.S. economic endurance in the next century. But it must be recognized that all investment is not good investment. If one region grows at the expense of others without generating a net addition to the sum of all economic activity, there will be no contribution to economic growth and living standards for many will stagnate and decline.

PRIMER ON STRATEGIC PRINCIPLES

The economic vision for state and local transportation executives may thus be characterized as: Advancing the cause of enhanced economic growth while promoting regional economic priorities.

Strategies for translating this vision into measurable economic objectives must thus harmonize the twin needs of transportation executives to (i) establish policy objectives in the light of regional economic, political and social priorities with (ii) the search for transportation investments that lead to net gains in productivity and economic growth. Successful strategies will rest upon four key principles:

- Objectives must be defined before an evaluation methodology is selected;
- Objectives should be stated precisely and realistically;
- Objectives must provide a clear framework for the choice of evaluation methodologies; and
- Objectives must balance the common goal of economic growth through capital formation and productivity with regional economic aims.

Defining Objectives Up-Front

In the past, it has not been unusual for infrastructure analysts to make methodological choices without linking them to a detailed review of objectives with their executive decision makers. A given methodology however only measures the achievement of certain objectives and signals nothing about any others. Unless the objectives are established first, there is a major risk that the information upon which executives will be obliged to base and defend decisions reveals nothing about the aims they might actually wish to accomplish. This indeed is a common characteristic of many past evaluation studies.

A sound strategy of decision should thus involve executives in the formulation of objectives and these should be formulated for each policy or investment program to be evaluated.

Defining Objectives Precisely

Decision makers need to ensure that the objectives specified in policy, program and project proposals describe desired future states against which progress can be unambiguously measured. This does not necessarily mean that economic aims have to be expressed in numerical terms, which of course will often be neither possible nor appropriate. But it must always be possible to derive from them agreed and appropriate quantitative yard-sticks which can be used to judge, without ambiguity, the extent to which they are likely to be (or are being) achieved.

Decision makers must also be assured that their objectives are realistic, or "**operable**" in the sense that (i) infrastructure investment should be a practical means of achieving them and (ii) there should be suitable means for achieving them over which the responsible authorities have some control. An airport expansion, for example, would reasonably aim to reduce congestion and generate energy savings and net productivity improvements for business travellers. An expanded airport would also expand its workforce and thus be a potential source of increased employment for disabled people and other minorities. But it would not be sensible to assign an employment-equity objective to the airport plan as a basis for decision[5] since transportation policies and investment can have little direct impact on employment-equity generally and transportation authorities have little control over labor market policies overall.

A Framework for Methodological Choice

Different methodologies measure different aspects of economic performance; a vague or confusing array of economic objectives can thus lead to the choice of evaluation methodologies which answer the wrong question and promote inappropriate and ineffective decisions. Unless decision makers assure themselves that objectives adhere clearly to the twin strategic principles of regional economic progress **and** productivity and economic growth, analysts will be drawn to evaluation methodologies and measurement techniques that fail to reveal the effectiveness of policy alternatives in promoting the objectives of interest.

Balancing Regional Aims with the Goal of Economic Growth

It is logically impossible to choose a unique policy or project on the grounds that it gives the best performance in attaining several independent objectives, unless the alternatives being considered all push in the same direction towards achieving them. This is rarely the case. A transportation policy or investment that attracts employment to a region will only foster economic growth as well if the same level of employment could not have been achieved through other spending or fiscal policies. Since this can rarely be demonstrated, it means that if state (and federal) funds for infrastructure were dispersed solely on the grounds of reducing regional disparities in employment and income, the overall level of economic growth might fail to achieve that needed to sustain living standards generally. Conversely, if state aid was available only to local projects with the highest potential pay-off for economic growth, many cities and rural areas would never see any transportation improvements.

Neither of the extremes outlined above is acceptable and a balance can only be struck by:

- Choosing just one objective as the most important and treating all the others as constraints; or

[5] It would of course be acceptable to apply employment-equity policies to the expanded airport if a decision to undertake the project were to be approved on other grounds.

- Converting the several objectives into a single one by assuming a predetermined trade-off between them (the Benefit-to-Cost Ratio effectively does this); or

- Searching for solutions which are satisfactory or "good enough" rather than optimal.

Surprisingly, any of the three strategies will work; the important message is to be precise about the objectives and constraints and to express what "good enough" means in measurable terms. At a minimum, decision makers need to assure themselves that policies and programs will make a net contribution to economic growth. Executives do not have to settle for only the most highly stimulative projects; a poorer locality might warrant project funding even though its proposal offers less potential for productivity growth than the proposal of a wealthier region. But **any** project should offer at least a minimum net contribution to economic growth to stay in the running. Otherwise, the sum of all infrastructure investments nationally will fail to make the necessary contribution to the nation's pursuit of 0.8 percent-plus productivity growth and 3.5 percent-plus economic growth needed to sustain living standards. How decision makers can define the "minimum net contribution" and judge whether policies and projects are likely to achieve it is the subject of this and later chapters.

PRIMER ON PROCEDURES AND TECHNIQUES

Decision making strategies warrant the involvement of transportation executives in the development of objectives for each infrastructure policy or investment plan to be evaluated as a basis for decision. Executives thus require a clear understanding of:

- The range of possible economic objectives;

- The principle distinctions in the economic meaning of alternative economic objectives; and

- Strategies for balancing multiple objectives and developing minimum requirements for their achievement.

Alternative Economic Objectives for Infrastructure Policy

Regional economies are variegated and complex in nature and the range of economic objectives pursued by states and localities is thus exceedingly broad. The first job of the executive is to ensure that the objectives assigned to transportation policies and investment programs are realistic -- that they do not aspire to influence aspects of the economy over which transportation authorities have little control or to achieve aims that are better served by non-transportation policies.

There are seven areas of economic activity in which it is justifiable to establish objectives for transportation policy. These are aspects of the economy in which the influence of transportation policies are verifiable and potentially significant:

1. **The distribution and structure of employment** -- the geographic distribution of remunerative jobs both directly and indirectly associated with the transportation system and the skill and income characteristics of employment;

2. **The distribution of personal income** -- the share of total output and income obtained by groups at different levels of income;

3. **The distribution of regional output and income** -- the share of production and economic output obtained by different geographic regions;

4. **The distribution of sectoral output and income** -- the share of total production and output attributable to particular industrial and service sectors;

5. **Growth in productivity** -- increased production of goods and services per hour worked;

6. **Growth in economic product and output** -- increased total production valued at market prices (namely, Gross National Product or the gross product of a specified state or region);

7. **Growth in total economic welfare** -- increased economic benefits that exceed the increased economic costs of achieving them. "Welfare" is distinguished from "output" in that welfare includes factors, such as time and safety, that have economic value but are not included in the normal accounting definitions of economic output and gross product.

Two frequently cited economic objectives -- "improved living standards" and "economic development" must be defined within the framework of the seven objectives outlined above.

Improved Living Standards. The term "standard of living" relates to all aspects of daily life that individuals value. This includes both the goods and services people buy and whose value is reflected in measures of gross product as well as the economic factors, such as time savings, safety and reduced pollution, that are not included in gross product but for which people are nevertheless willing to pay. To achieve an **increase** in the standard of living, it is necessary to achieve an increase in the availability of items people value (more refrigerators, less congestion) that exceeds the value of any economic resources used up to achieve the increase (such as more steel production, more freon emissions and more highway construction). Improved living standards thus equate to objective 7 above, growth in economic welfare.

Economic Development. The term "economic development" cannot be assigned a precise definition, but rather depends upon how the decision maker selects among the seven objectives outlined above, how they are prioritized and the minimum conditions established for their achievement. If increased employment in a region is valued for its own sake, regardless of the economic costs of achieving it, then a transportation policy or investment that secures more jobs in the area may be considered economic development. But if employment growth is viewed as a means of achieving **both** jobs and a gain in the standard of living, then executives will need to establish both objective 1 and objective 7 as the basis for decision making. Only policies or investments that achieve both objectives simultaneously would then be regarded as economic development.

The definition of economic development will thus vary from state to state (and decision to decision) depending upon the objectives chosen by executives and decision makers and the balance struck between them. Choosing and balancing the economic objectives of transportation policies and investment choices is thus tantamount to establishing a strategy for economic development.

Key Distinctions in the Economic Implications of Alternative Objectives

The seven objectives are distinct in terms of (i) the various aspects of economic activity they seek to influence and (ii) in terms of transportation's influence relative to other (non-transportation) policies in achieving the various economic outcomes.

The Relationship Between Alternative Objectives and Distinct Aspects of Economic Activity. In shaping the transportation aims of state or local economic development strategies, executives need to contemplate two principal distinctions among the key objectives at their disposal:

- Objectives relate to either the distribution of economic activity (how the pie is shared) or to growth in the volume of economic activity (the size of the pie to be shared); and

- Growth-related objectives refer to either growth in productivity and gross product as ends in themselves, or to growth in economic welfare and living standards, with increased productivity and gross product as means to their achievement.

Distribution versus Growth. Four of the seven objectives (objectives 1-4) relate principally to the distribution of economic activity.

The uneven distribution of economic prosperity, both nationally and among the regions and localities of individual states, has long been a priority of state and local policy makers, including those involved in transportation. Although the effectiveness of transportation policies in relation to other ways that states and localities can direct the spread of economic prosperity varies in relation to the objective listed (see next section), transportation can have a measurable influence in each area.

Three of the seven objectives (objectives 5-7) relate principally to growth. The rate of growth in productivity, output and the standard of living has traditionally been the principal concern of macroeconomic policy decision makers. Today, however, a critical role has emerged for those with authority over capital investment and this is true in both the private and public sectors. Consider the following quotation from the Brookings Institution Review;[6]

> If the United States wants to take advantage of the robust high correlation between capital per worker and

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[6] Ralf Landau, **Capital Investment: Key to Competitiveness and Growth,** The Brookings Review, September 1990.

> growth and raise real living standards, it will need to adopt stable policies favoring long-term investment. The business cycle and long-term growth must be viewed from one overall perspective. Economists may quarrel over whether growth stimulates investment or vice versa, but in practice the order is immaterial. Supply is no longer assured, even if demand is stimulated, because of the long gestation periods now required to adopt technology more efficiently. What matters is that investment in **productive** physical capital can promote growth, as can the proper and stable management of macroeconomic policy by the government and of individual companies by the private sector.

The general macroeconomic climate for capital investment (long-term interest rates; funds for research and development; federal concern for infrastructure funding and so on) is continuing to adapt to these challenging new perceptions. The onus is now upon transportation executives to recognize growth-related objectives in addition to the more traditional focus on distribution in establishing the aims of transportation capital investment programs in their states and localities.

It should be noted that policies and investments that influence the distribution of economic activity can also result in growth, and vice versa. However, since different methodologies are required to measure the distributional and growth implications of any given policy or investment proposal, it is important to specify each objective of interest in establishing a decision making strategy. In this way, decision makers can ensure that the full range of information needed as a basis for decision will be available.

Gross Product versus Welfare. Having recognized that economic growth represents a legitimate object of transportation policy and investment, executives need to explore the alternative components of economic growth as a basis for decision making.

Although productivity and economic growth (objectives 5 and 6) are becoming the marching song of capital investment, public officials realize that circumstances arise in which growth is acceptable only if the economic costs of achieving it do not represent a disproportionate drain on living standards. Environmental regulations clearly limit the growth rate in gross output and income; they are put in place and accepted when the economic value of the cleaner air and water they achieve is believed to exceed the benefits that people will forego as a result of smaller increases in income. Objective 7 should be adopted if executives view increased living standards as the ultimate growth-related objective, with increased productivity and economic growth as the principal means of achieving it.

The adoption of a growth perspective creates a vital incentive for state and local officials to seek out those transportation investments likely to have the most profound impact on productivity. It has only recently been discovered that conventional methodological tools fail to measure the impact of transportation improvements on the productivity of private firms. Highway network improvements, for example, can do more than reduce congestion and vehicle operating costs. They can also lead firms to adopt new technologies and management logistics that facilitate lower inventories, fewer storage depots and other savings that improve productivity. Unless such gains are identified in association with prospective new projects, there is a real danger that good projects will be mistaken for bad ones when understated benefits are compared to construction and operating costs and environmental impacts.

The growth objective thus makes it vital for state and local transportation executives to ensure that, to the fullest possible extent, all prospective productivity impacts associated with investment possibilities are identified in the evaluation process. Chapter 3 considers this problem in-depth.

The Relative Effectiveness of Transportation in Achieving Alternative Objectives. Executives need to insist upon a careful analysis of policy and investment alternatives in order to obtain information on the extent to which specific objectives are likely to be achieved by any given policy or investment proposal. But in establishing the strategic goals of an economic development strategy for transportation, decision makers need to know what is known about fundamental differences in the relative effectiveness of transportation policies in achieving alternative aims.

In summary, the weight of both economy-wide and specific investment-related research (macro and micro-economic investigations) indicate that transportation infrastructure investment is substantially more effective in promoting net productivity growth than it is in stimulating regional economic gains. Using macroeconomic models of the economy, research indicates that capital investment is the principal source of productivity growth. Studies by Professor Robert Solow of the Massachusetts Institute of Technology (and winner of the 1987 Nobel Prize for Economics) attribute up to 85 percent of past growth in GNP to productivity increases (as opposed to increases in the quantity of labor or capital).[7] The importance of capital investment to productivity has been confirmed by Professor Dale Jorgenson of Harvard, whose studies suggests that the productivity of labor is significantly affected by the per-worker rate of capital investment -- the amount of money spent in building up the nation's capital stock.

Macro-economic studies indicate that transportation policies and investments make very little difference to total employment and related income in a region. While studies often report large number jobs either directly or indirectly associated with transportation facilities, more in-depth investigations find that virtually all employment associated with expansions of the transportation system in mature economies would be absorbed elsewhere in the labor market if the investment were not to take place. Only where a regional economy displays long-term structural unemployment can regional net gains in employment and income stem from transportation policies and projects. Even then, the gains are typically small (see Box 1).

At the level of individual investments, which of course can vary widely in their economic performance from very strong to very weak, micro-economic analyses indicate that rates of return can sharply exceed those being achieved by private firms, thus signifying important gains for productivity.

Case studies (see in particular Box 1 below and Box 4 in Chapter 3) indicate that many transportation infrastructure investments yield rates of return up to 10-times the yield on typical private sector investments. Box 4 in Chapter 3 also indicates that many such investments are long-overdue, as much as 10 years in some cases, from the viewpoint of spurring productivity and economic growth. Taking the case studies reported in Boxes 1 and 4 together, it is evident that policies and investments aimed at reducing congestion and increasing the extent of automation in transportation systems offer especially high gains in productivity and economic growth. Congestion and aging technologies may thus be viewed as bottlenecks not just to traffic, but to productivity and economic growth itself.

On the other hand, the impact of such projects on the distribution of regional economic activity (employment and income in particular) are very modest in relation to the overall size of regional

[7] For a useful summary, see **U.S. Economic Growth,** Scientific American, June 1988

economies, indicating a much smaller relative distributional impact[8] (see Box 1).

While productivity gains alone can often justify transportation investment, this is rarely the case with employment, income and other targets of regional redistribution.

Executives can conclude from the summary that transportation policies and programs can indeed result in economic growth. In relation to the sources of economic growth -- the number of workers and the productivity of workers -- transportation fosters growth almost exclusively through the latter. The more in-depth discussion presented next offers a deeper examination of this important issue.

In more detailed terms, the effectiveness of transportation on the achievement of alternative objectives can be compared in relation to two standards:

- The comparative effectiveness of transportation versus non-transportation policies for obtaining the same outcome; and

- The comparative effectiveness of transportation investments relative to the status quo or "base case."[9]

The first comparison is relevant when transportation officials are developing a case for transportation budgets in competition with social services, education and other non-transportation programs. The second is relevant when executives are making decisions on transportation investments per se.

Table 1 provides an overview of relative effectiveness against each comparative standard.

Effectiveness of Transportation in Promoting Redistribution of Economic Activity. In comparison with non-transportation approaches to achieving redistributional objectives, Table 1 indicates that the effectiveness of transportation policies and investments is in the low to low-to-moderate range.

Most analysts conclude that a relative lack of employment, income and business potential in economically weak regions and localities is less likely to result from inadequate transportation than from a shortage of other factors such skilled labor, strong geographic advantage and

8 In a 1989 study of the feasibility of constructing a four-lane highway from St. Louis, Missouri to St. Paul, Minnesota (the proposed "Avenue of the Saints"), the regional economic employment and income distributional impacts were found to be very small (less than $20 million in relation to project costs of $359 million) while the productivity impacts (including savings in vehicle operating costs and business time) were found to exceed total costs by $74 million. See, David J. Forkenbrock, **Do Highway Investments Spur Economic Development?** Prepared for, First Annual Transportation Research Conference, Center for Transportation Studies, University of Minnesota, May 3, 1990.

9 The base case concept, presented in detail in Chapter 4, is an extension of the status quo that involves steps to ensure the most efficient operation of existing transportation infrastructure.

BOX 1

CASE STUDY

Impact of Transportation on Productivity Versus Regional Economic Expansion

A 1990 study examined (i) the economic rate of return and (ii) the attraction of jobs and income to the region in association with the construction of a new runway at the highly congested Vancouver International Airport.

Impact on Productivity

The analysis concluded that the runway would yield an economic rate of return of 114 percent, more than 10 times the yield on typical private section investments and far greater than even the most well performing private capital investments. A very similar result emerged from airport expansion studies at Minneapolis-St. Paul. The Congressional Budget Office reports rates of return for new highway construction in congested urban areas of 12-15 percent and over 40 percent for reconstruction projects in crowded segments of the Interstate Highway System. These returns are not as dramatic as those reported above but well above the social cost of capital and returns in the private sector.

Impact on Regional Economic Expansion

The Vancouver analysis found that a new runway would yield $250 million annually (in 1988 dollars) in additional employment and income for the region. This amount is less than the total projected employment impact of the project and represents the portion that would not be absorbed by other regional labor markets in the absence of the project due to long-term structural unemployment in the region. The $250 million in economic activity represents only 0.6 percent of total gross output for the region (British Columbia). From this, the study concluded that while the productivity gains alone were sufficient to justify runway construction, the distributional impacts were not. Nevertheless, the distributional impacts on the regional economy were seen as important considerations in the decision making process.

agglomeration economies. Initiatives in education and tax benefits to off-set industry costs associated with geographic disadvantage are thus more likely to yield effective results.[10]

To be sure, transportation infrastructure is a necessary part of a well developed regional economy. Most studies suggest, however, that even less well-off regions in a mature economy like that of the United States can sustain increased levels of economic activity with existing infrastructure. Once having done so, large-scale transportation improvements are likely to become demonstrably worthwhile from a growth perspective in that the benefits of new or expanded transportation systems exceed the costs of achieving them.[11]

The overview presented above relates to the long-term effectiveness of transportation systems. What about transportation investments as a means of countering the short-term regional impacts of recession? Here analysts are largely in agreement that major capital projects are less effective than non-transportation measures in boosting employment and income during dips in the business cycle. Capital projects take time to gear up, creating a risk of inflationary pressure if they continue into the post-recession period of growth.

In comparison with no alternative policy spending at all (the status-quo) or relative to a base case, transportation policies can certainly result in greater employment, income and output in a region. Typically, such gains are small in relation to the size of the economy overall, even in the case of major corridor or airport investments, since their multiplier effects do not reverberate significantly through all sectors of the regional economy.

Executives will recognize possible exceptions to this conclusion in the case of certain sectors, such as mining, where the presence of a plant or facility hinges upon the provision of infrastructure. The provision of at least a base level of infrastructure in most localities, however, suggests that such instances will be rare and not subject to generalization.

Effectiveness of Transportation in Promoting Growth in Economic Activity. In contrast with the potential effectiveness of transportation policies in attaining distributional aims, there is considerably greater potential in achieving objectives for economic growth. In comparison with the effectiveness of non-transportation policies, the most significant potential for transportation exists in relation to the objective of improved economic welfare and living standards. This stems from the direct effect that transportation improvements can have on productivity losses associated with congestion and delay (with associated losses in efficiency); economic waste in terms of vehicle operating costs (fuel, oil and depreciation in particular); vehicle damage and accelerated depreciation from pavement deterioration (for roads and runways in particular); and accident costs. Very few non-transportation policies can offer as high a direct return in these areas

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[10] For a useful review and bibliography on this question see, David J. Forkenbrock, ibid.

[11] Some studies find a statistical relationship between total employment and the advent of highway improvements. There is no evidence in these studies however that the transportation investments did not **follow from** the growth in employment. See for example, Jesse L. Buffington and Dock Burke, **Employment and Income Impacts of Highway Expenditures on Bypass, Loop and Radial Highway Improvements**, Federal Highway Administration, November, 1989.

TABLE 1:
OVERVIEW OF POTENTIAL EFFECTIVENESS OF TRANSPORTATION POLICIES IN ACHIEVING ALTERNATIVE ECONOMIC OBJECTIVES

	Potential Effectiveness Relative to Non-Transportation Policies	Potential Effectiveness Relative to Status Quo or Base Case
Distributional Objectives		
1. Employment	Low	Low/Moderate
2. Personal Income	Low	Low/Moderate
3. Regional Output	Low	Low/Moderate
4. Sectoral Output	Low/Moderate	Moderate/High
Growth Objective		
5. Productivity	Moderate/High	High
6. Output	Moderate/High	High
7. Welfare/Living Standards	High	High

relative to the costs of achieving them.

In the promotion of industry productivity and output objectives, large-scale transportation network improvements can help facilitate technological innovation and improved logistics, particularly in the area of inventory holdings and control. Transportation of course is one of many policy instruments that are available to help improve productivity growth. Executives need to consider transportation alongside education and training programs, improved tele-communications and enhanced research and development in developing overall strategies for improved productivity. Transportation programs can be very effective indeed in creating opportunities for growth in industrial productivity, but cannot lay claim to a disproportionate influence without a detailed evaluation of each policy and investment proposal.

In comparison with the status quo, transportation policies and investments can pay-off handsomely in all facets of economic growth. As shown in Table 1, the pay-off can also be very small, depending upon the quality of the initiatives under consideration, indicating the need for a careful evaluation of each policy and investment proposal (see Chapter 3). But in terms of transportation's **potential**, a well conceived investment program can yield strong gains in productivity growth, increased output and higher standards of living.

Does Transportation Stimulate Net Productivity and Growth through Productivity or through Employment? A state's economy can grow -- produce more goods and services -- either by employing more workers or by increasing the output per worker (productivity). Similarly, investment can stimulate growth either by stimulating employment growth, by spurring growth in productivity or by achieving both.

The weight of available evidence suggests that while transportation policies and investments can promote local employment, job creation is typically at the expense of employment growth elsewhere in the state (or in other states). Special -- and rather complex -- analyses are needed (see Chapter 3) to establish whether the employment and related ripple (or "multiplier") effects of transportation policies actually add to a states' gross output. In most cases employment-generated growth is small or insignificant, especially when viewed in relation to the costs of achieving it through transportation investment.

Economic growth from capital investment in transportation stems principally from productivity rather than employment growth. Time savings; more vehicle and aircraft miles per gallon of fuel and oil consumed; longer vehicle lives; reduced inventory costs -- factors such as these represent gains in productivity and almost always account for an overwhelming share of the gains from transportation investments. What employment gains there are tend to be redistributional, drawing growth from one part of the state to another.

The stimulation of jobs is almost always a concern of states and localities and, like other public officials, transportation executives can often "sell" their programs in terms of employment impacts quite effectively. The conclusions reported above do not mean that transportation executives need to discard employment as a selling point of their programs. For there will always be employment in association with transportation investments even if job-creation is not the grounds of the investment decision. Moreover, employment through redistribution is often regarded as an objective in itself. The real question raised by these conclusions is how employment should be regarded by executives in establishing strategic objectives and in making transportation policy and investment decisions. This is the subject of the next section.

Does Transportation Stimulate Net Productivity and Growth in Spite of Negative Environmental Impacts? A great many infrastructure policies and investments are held up, often indefinitely, due to environmental concerns. Recent economic assessments of specific projects indicate that while environmental impacts create real economic costs, investments that reduce highly congested systems create far greater economic benefits. The critical issue therefore is not whether such transportation investments are environmentally sustainable, but rather how to devise policies that make a portion of the benefits available to finance the mitigation of negative environmental impacts.

As a case in point, a recent economic evaluation of a new runway at a Vancouver International Airport[12] used Risk Analysis to determine the reduction in land value and the economic losses in householder welfare from associated increases in aircraft noise. The evaluation determined that while there is an 80 percent probability of the economic costs of noise exceeding $35 million (in present-day value over 20 years) for the affected neighborhoods, there is an equal probability that economic benefits (from time savings to passengers and fuel savings to aircraft) would exceed $4.0 billion. This means that less than one percent of the benefits would fully compensate for the full environmental impact. The transfer could be achieved through special taxes on airline passengers or user fees to airlines; and compensation could take the form of cash payments, insulation programs or other means.

Whatever the mechanism, the evidence indicates that the economic costs of transportation policies offer no justification in themselves to paralyze worthwhile investments.

Strategies for Defining Economic Development in the Context of Multiple Objectives

Two major conclusions stem from the discussion thus far:

- Transportation policies and investments are more effective in promoting economic growth than they are as instruments of economic redistribution; and

- Transportation policies and investments promote growth through productivity gains rather than net increases in the rate of employment.

From the viewpoint of defining a framework of economic development objectives for state transportation policy and investment, the above suggests that value for the transportation dollar will be maximized by focusing foremost on growth related policies and investment programs and treating redistributional goals as important, yet subordinate aims (see Box 2). The subordination of redistributional goals by no means implies that executives need to abandon transportation as a means of helping diminish regional disparities in income and services. Rather it implies a two-step decision making strategy:

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[12] Transport Canada, **Economic Analysis of Airfield Capacity Enhancement Strategies for Vancouver International Airport,** March 1990

- All policies and investments must demonstrate the likelihood of yielding a minimum-required contribution to economic growth;

- Policies and investments that pass the "growth test" obtain priority in the capital budget in relation to redistributional goals.

Under this strategy, executives seek out investments that promote productivity and growth but they do not necessarily select those which **maximize** growth potential. If there are two competing investments, both of which achieve the minimum-required growth potential, executives could legitimately decide upon the lower of the two achievers if doing so directs investment to an area under more economic stress -- or, indeed, to an area with a greater political claim to investment. Growth under the strategy outlined above is achieved through transportation investment without sacrificing regional and sub-regional social and political priorities. And regional and local priorities are addressed without spending on non-achieving investments from a growth perspective (a rather common practice over the past 20 years[13]).

What is eliminated under this strategy is "pork barrel spending that spreads money around with no net economic effects."[14]

How can a "minimum-required contribution" to economic growth be defined in practical terms? The operational approach to establishing a minimum-required contribution to economic growth is through use of the rate-of-return concept commonly applied in investment planning generally.

The key question for executives of course is deciding what the minimum rate-of-return on transportation investments ought to be. The answer turns upon which of the three concepts of economic growth it is that decision makers seek to influence -- productivity; gross output; or economic welfare (i.e., living standards).

Productivity. If productivity alone is chosen as the object of growth, any investment that increases the value of marketed goods and output per worker can be accepted if it is likely to yield a rate of return at least equal to that achieved, on average, by private firms. The federal Office of Management and Budget recommends a rate of 10 percent (in constant dollars) as the appropriate hurdle rate in this context. This rate is akin to the "social opportunity cost of capital" concept outlined below under the **economic welfare** heading.

Gross Output. If gross output alone is chosen as the objective of growth, any investment that is likely to lead to an increase in total production can be accepted if it achieves at least a positive rate of return.

Economic Welfare. If growth is only to be considered acceptable in cases where any sacrifice in living standards required to achieve it is publicly acceptable, decision makers must insist that

13 National Cooperative Highway Research Program: **Supplement to NCHRP Report 342: Primer on Transportation and Economic Development: Technical Report,** December 1990.

14 See Daniel Brand (in) **Special Report 220; A Look Ahead -- Year 2020,** 1988 (page 20).

BOX 2

CASE STUDY

Choice of Objectives

Some state-level investment evaluations give substantial weight to economic growth as a principal objective while continuing to recognize the redistributional objectives of regional policy. As evaluations conducted for a major international airport cited the following questions in underscoring its objectives and priorities;

1. Would enhancing existing facilities, technological innovation and traffic management and pricing be sufficient to diminish congestion and delay by enough to cancel or defer the economic justification of a new runway or the development of alternative airports?

2. Of the various investment strategies available, which offers the greatest economic return? Is the return greater than the social opportunity cost of capital?

3. What level of regional employment and income growth would arise in response to the alleviation of capacity constraints?

The evaluation recognized objective (1) as a means of avoiding unnecessarily large-scale investment; objective (2) as a means of contributing to net economic growth; and objective (3) as a means of promoting employment and income gains in the region. The evaluations asserts the achievement of objective (2) as a necessary condition for investment and objective (3) as a major consideration.

the rate of return on transportation investments (i) exceed the return that these funds would yield if invested in the private sector; and (ii) include an allowance for the extent to which people are willing to sacrifice present consumption of goods in services (ie, living standards) in lieu of thefuture benefits to flow from the investment.

This standard is known as the "social opportunity cost of capital" because it accounts for society's willingness to forgo consumption today in exchange for the future benefits of capital investment. In practical terms, its application as a minimum requirement means that investments must yield a rate of return at least equal to the public authority's borrowing rate (currently projected by the Congressional Budget Office at 3 percent to 4 percent in real terms). This procedure ensures that investments not only foster productivity growth, but that they foster an **amount** of productivity growth whose economic value exceeds the cost of the capital and other resources expended in order to achieve it -- including the social cost of forgoing the use of funds in the nearer term.

Choosing a Minimum Growth Criterion as a Matter of Policy. The promotion of productivity and growth as ends in themselves has been the choice of many nations, especially those in the developing world. Decision makers need to understand, however, that doing so implies the belief that the social opportunity cost of capital is zero (i.e., that no social opportunities, such as improved material living standards, are foregone when dollars are set aside for investment). Virtually no-one in the United States today would subscribe to that view, suggesting as it does that Americans would be willing to sacrifice very heavily indeed in terms of current living standards (to the point where some would literally starve) in order to boost the rate of growth in output. Indeed, to finance all transportation investments that promise positive rates of return (without competing unduly with the private sector for debt capital) taxes would need to rise very substantially -- a step that is clearly out of step with national priorities.

As well, since the accounting conventions used in measuring productivity and growth exclude factors such as the safety, health, congestion, delay and other factors with real economic value, the maximization of productivity and growth for their own sake limits the search for investments to those with direct income-earning potential. Since many highly productive transportation investments do not have direct income-earning potential (such as congested freeway improvements, for example), productivity and growth in themselves represent limiting targets of state economic policy for transportation.

Choice of the welfare objective, on the other hand, offers substantial advantages. It promotes investments:

- That yield substantial productivity and growth;
- That promote economic benefits whether or not they are counted in the national accounts of income and output; and
- That lead to neither under nor over-investment in relation to the public's willingness to invest now in return for future rewards.

Use of Net Present Value as the Correct Policy Criterion. In application, the welfare criterion also permits transportation projects and policies to be ranked in order of their contribution to productivity and economic growth. As discussed in Chapter 3, the ranking of policies and programs requires the use of a procedure whereby the minimum-required rate of return (the social opportunity cost of capital) is used to relate all forecasts of future costs and benefits on a comparable footing by computing their equivalent present-day values. This procedure accounts for the fact that different policies create costs and impacts at different rates over time. The present value of the costs is then subtracted from the present value of the benefits, resulting in a "net present value." If the net present value of a program or project is greater than zero, it means that its rate of return exceeds the social opportunity cost of capital and may thus be judged to promote worthwhile gains in productivity.

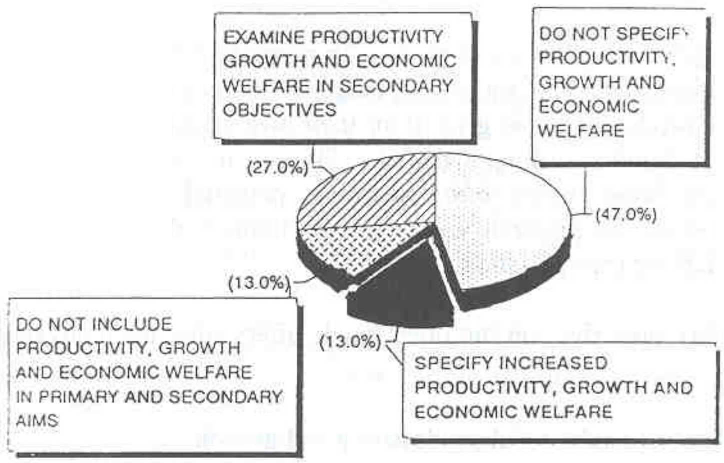
Moreover, the higher the net present value, the more economically worthwhile it is and the more productivity and growth it will promote. As a rule, the decision maker should always insist that policy and investment proposals are evaluated in terms of their net present value.

Applying the Minimum-Required Growth Criterion in a way that also Satisfies Distributional Objectives. Decision makers often find themselves in situations where the approval of an investment program or project is compelling for distributional reasons or for reasons having no economic content. Under these conditions, executives can seek to ensure that the investment has at least minimally-acceptable growth characteristics by applying the welfare

BOX 3

SURVEY OF CURRENT PRACTICE: 1990

Choice of Objectives



Only 13 percent of policy and investment evaluations examined in the 1990 Survey of Current Practice specified increased productivity, growth or living standards (economic welfare) as principal economic objectives for transportation. A continuation of this trend will foster transportation systems that sharply under-perform in the pursuit of revitalized productivity and real income growth through capital investments.

test but without insisting on funding only the highest pay-off projects. A number of states, for example, begin the budgetary process by first allocating transportation program budgets geographically according to sub-regional equity considerations. Only then are program and project evaluations conducted. Under this approach, programs and projects should be ranked within sub-regional budget allocations according to their performance against the net present value criterion, thus satisfying the strategic aim of "advancing the cause of enhanced economic growth while promoting regional economic priorities".

Formal ranking will not always be possible because of limited data; it should always be possible however to conduct the welfare test on each proposed investment to ensure a minimum contribution. An investment that fails against the welfare criterion defers scarce capital dollars from more productive investments. From the viewpoint of economic growth, it should be rejected, even if its redistributional consequences are desirable from a local or regional point of view. If, however, there are compelling reasons to give the investment further consideration, the output test for a positive rate of return can be applied. If the investment fails even this test -- it is projected to yield a negative return on investment and thus lead the economy to contract -- the decision maker will have an equally compelling case to resist approval, perhaps asking for a restructuring of the proposal in order to improve its potential.

PRIMER ON GOOD PRACTICE AND COMMON ERRORS

The force of available evidence suggests strongly that transportation policies should seek out and favor investments that promote productivity and improved living standards through economic efficiency rather than those which dissipate capital dollars for distributional reasons alone.

Good practice for decision makers in establishing the objectives of transportation policy and investment programs spans the following four principles:

- Take the time to spell out policy and program objectives before the development and analysis of alternatives begins. Remember that unless objectives are properly articulated up-front, the wrong information is likely to be made available as a basis for decision;

- Executives should work closely with program managers and analysts to ensure a clear understanding of the objectives. Executives should also confer with stakeholders throughout the state to ensure all have a complete understanding;

- Where objectives can come into conflict, subordinate some to others and give meaningful weight to economic growth. Be specific about priorities and minimum requirements, provide ample explanation to stakeholders, and resist undue pressure to water down growth-related imperatives; and

- Be consistent, but develop objectives separately for each independent policy or program initiative.

Two errors are quite common in recent practice. The first is a marked confusion between distributional aims and aims relating to economic growth. It is not unusual, for example, for the projected employment and related economic ripple effects of an investment to be regarded as evidence of economic growth and singled out for measurement as key program objectives. Executives should ensure that the objectives they carve out distinguish clearly between distribution and growth and that these are used by program managers and analysts as the foundation of the evaluation process.

A second common error is failure to conduct the kind of analysis needed to measure the prospective growth implications of policy and program options. In many cases, the only information generated for decision makers relates to the distributional implications of policy and investment alternatives (often in the mistaken belief that the data does convey information about growth).[15] Once assured that their objectives are properly specified, executives should make sure that program managers and analysts plan to adopt methodologies and criteria (especially net present value) that are designed to yield the information required for decision making. Chapter 3 of the Primer provides the Executive and the program manager with the necessary guidance.

[15] National Cooperative Highway Research Program: **Supplement to NCHRP Report 342: Primer on Transportation and Economic Development: Technical Report,** December 1990.

PRIMER ON TECHNICAL LANGUAGE AND ITS INTERPRETATION

Executives need not develop a command of technical jargon -- indeed, decision makers should place the onus on program managers and analysts to make the language of economic analysis accessible to all, including the general public.

Certain terms, however, are drawn from common language but have come to occasion rather specific meaning. In the context of establishing objectives, three expressions stand out in particular, namely distribution, economic welfare and economic efficiency.

Distribution

The distributional effects of policies and investment programs are those which alter the way total income is shared without changing its volume.

Welfare: A Synonym for Standard of Living

The economist's term "welfare" may be used interchangeably with the term "standard of living." Welfare, or standard of living, effects of projects alter total production and consumption opportunities for households, individuals and firms. As noted earlier, executives need to be on guard to distinguish the distributional and growth effects of policies and investments.

Economic Efficiency, Welfare and the Standard of Living

The so-called "welfare benefits" of policies and investment programs represent opportunities to increase production or consumption, including the production and consumption of improved safety, less congestion and other items that are not included in normal measures of economic output and consumption. The "welfare costs" are the opportunities for production or consumption that would be foregone if a policy or investment is undertaken. A project may be viewed as one that increases the standard of living if the welfare benefits exceed the welfare costs.

A policy under which welfare gains exceed welfare losses may also be regarded as "economically efficient" in the sense that, in theory, a different use of the same funds would yield smaller gains in living standards. While data and measurement difficulties make it impossible to identify the theoretically ideal use of funds in each case, aiming to do so helps guard against waste in the use of scarce budgetary dollars for transportation. Ultimately, only the executive's judgement in the use of measurement information should provide the definitive basis for action.

Rate of Return

Rate of return refers to the percentage of total investment cost recovered in the form of economic benefits on a periodic basis. Economic benefits include the total value of reductions in vehicle operating costs, time savings, reduced risk of accidents, enhanced business and industry productivity and other economic pay-offs. Rate of return is usually expressed on an annual basis, namely the percentage of total investment cost recovered, on average, each year over the economic life of project. With transportation projects, rate of return often increases annually as traffic levels grow and thus generate progressively higher benefits. It is thus important to examine *when* the rate of return enters the acceptable range in order to guard against projects whose economic merit hinge upon distant and thus highly uncertain forecasts. A good rule of thumb is that the rate of return should equal or exceed the minimum required rate of return the first year after a project's completion.

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CHAPTER 3

STRATEGIES FOR THE SELECTION AND USE OF METHODOLOGIES

From the executive's point of view, a "methodology" is simply a means of obtaining information to help guide policy and investment decisions towards the achievement of their objectives. Information is, without doubt, the decision maker's most important resource-- good information fosters good decisions while poor or inappropriate information fosters bad decisions.

The executive is accountable for the quality of information made available to decision makers. Decision makers, in turn, are accountable for the quality of the judgments they make. It is thus critical to both executives and decision makers that they ensure (i) the appropriate choice of methodology and (ii) the correct application of key methodological principles.

Different methodologies provide different kinds of information and must thus be chosen in relation to the objectives at-hand. Since the application of any methodological approach is expensive and time consuming, executives should help guide the choice of a methodological strategy before data collection and analysis begin. The Primer on Strategic Principles in this chapter counsels the executive in the design of a methodological strategy.

Methodologies can be complex in application but major mistakes usually occur in the misapplication of technical and procedural fundamentals. The Primer on Procedures and Techniques helps executives and decision makers monitor and probe the analytic process to ensure the sound application of methodology.

Even where there are no fundamental errors in application, methodologies inevitably rely to an important extent upon forecasts and engineering judgements and results are thus uncertain. Uncertainty creates risk in decision making and executives need to be equipped to provide decision makers with meaningful information about risk and to devise strategies for dealing with it. The Primer on Procedures and Techniques in this chapter discusses the nature and role of such strategies while Chapter 9 presents a more detailed guide to their application.

PRIMER ON STRATEGIC PRINCIPLES

Methodologies fall into three broad categories, as follows:

- **Indicative Planning Methodologies**, which aim to provide a broad indication of the volume of capital investment which may be warranted from an economic point of view;

- **Investment Choice Methodologies**, which provide guidance on the choice of specific investment programs and projects; and

- **Hybrid Investment Choice-indicative planning Methodologies**, which first establish a broad spending "envelope" based upon a reasoned evaluation of evidence from the application of indicative planning methodologies: and second, determine actual expenditures based upon the expected economic returns from each proposed spending program or project.

INDICATIVE PLANNING METHODOLOGIES

Indicative planning methodologies aim to provide an indication of generally appropriate budget and investment levels for transportation infrastructure. As the term suggests, these techniques provide, at best, an indication of generally appropriate capital budget and investment levels; they cannot substitute for investment choice methods in the selection of actual programs or projects. Various techniques are available, including the use of estimated asset lives and depreciation rates to forecast the quantity of investment required to maintain current services; and the analysis of transportation investment's impact generally on overall productivity. Salient features of these approaches are discussed next.

Based upon the statistical (econometric) analysis of historical economic data, newly emerging indicative planning techniques examine the role that public investments have played in the nation's economic growth. Statistical analysis is used to explore the nature of "aggregate production functions" -- namely, the correlation between growth in private sector productivity and growth in the labor force and the volume of private and public investment. Using statistical techniques, the analysis attempts to quantify (i) the extent to which infrastructure investment, other things being equal, has fostered productivity growth in general; (ii) the relative contribution of public and private investment to productivity and thus long-term economic growth; and (iii) the extent to which government investment in infrastructure has added to the nation's stock of productive capital (rather than simply substituting for private investment -- the so-called "crowding-out effect").

Indicative planning techniques use either asset life and depreciation rates, system condition and performance ratings or estimated macroeconomic relationships to signify the appropriate level of public investment in the future.

Depreciation and Condition and Performance Methods

This class of approach, used for example by the Canadian Department of Transportation, uses the estimated service life of transportation assets and assumed capital depreciation rates to establish the stream of annual capital expenditures needed to maintain the existing system.

A related method, used by many states, develops estimates of pavement condition, performance and deterioration rates and then forecasts the future investment cost to maintain a pre-set condition or performance standard.

Macroeconomic Relationships

Still in its infancy, this approach seeks to quantify the specific influence of aggregate private and aggregate public (infrastructure) investment on overall productivity and economic growth. The estimated relationship is then used to gauge the optimum balance between public and private investment.

As an example, consider the recent econometric studies of David Aschauer and Alicia Munnell.[16] Their statistical analyses yield estimates of the percent change in private secto productivity[17] corresponding to a given percentage change in the amount of private and public capital investment. Economists call this kind of relationship an "elasticity," a convenient numerical means of using statistical relationships to make forecasts. For example, if the "elasticity of productivity with respect to infrastructure investment" is 0.5, it means that a one percent increase in infrastructure investment is estimated to yield a 0.5 percent increase in productivity. By extension, a 10 percent increase in infrastructure investment is forecast to yield a five percent increase in productivity (ie, 0.5 multiplied by 10); and so on.

Aschauer's analysis indicates that the elasticity of productivity (and thus output) with respect to infrastructure investment[18] is in the range of 0.38 to 0.56. Using a longer historical period of analysis, Munnell narrows the estimated range to 0.31 to 0.39. Estimates of the elasticity of productivity with respect to increases in private investment and in the labor force are in the range of 0.3 and 0.7 respectively.

What indicative infrastructure spending levels are implied in these estimates? One implication of the Aschauer-Munnell equations is that the annual rate of return on additions to the stock of public investment is, on average, some seven times greater than the returns to private investment. In fact, the Aschauer-Munnell elasticities imply returns to public investment of as much as 146 percent and pay-back periods of a year or less compared with 21 percent annual returns to private capital formation, with pay-back periods of seven years or more.

The implied imbalance in returns to investment indicated above would suggest the need for a sharp increase in infrastructure investment to achieve the economically optimum allocation of capital dollars between public and private uses -- the optimum exists when an additional dollar of capital will yield the same return whether allocated to public or private investment. To achieve such a balance, the Aschauer-Munnell results imply that the stock of "core infrastructure"[19] would need to increase about five-fold. At the federal level, where 1989 infrastructure grants to states and localities totalled about $20 billion, these estimates imply a level of spending in the range of $100 billion annually for about 10 years in order to raise the public capital stock to the indicated level (assuming that State and local spending were to increase proportionately).

Advantages of Indicative Planning Methodologies

Since indicative planning techniques are based upon the analysis of historical data, they facilitate

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16 David Alan Aschauer, **Is Public Expenditure Productive**, Journal of Monetary Economics; Alicia H. Munnell, **Why Has Productivity Growth Declined? Productivity and Public Investment,** New England Economic Review, January/February, 1990.

17 Aschauer uses a measure called "total factor productivity," an index that reflects the combined output of both labor and capital inputs.

18 Aschauer's analysis refers to a "core infrastructure" consisting of streets and highways, airports, electrical and gas facilities, mass transit, water systems, and sewers.

19 See definition of "core infrastructure" in footnote 18.

policies that "learn" from the economic patterns of the past. In particular, the macroeconomic approaches can, in principle, reflect all impacts of transportation on productivity. Individual project choice techniques are traditionally partial in the sense that they do not attempt to trace the potential benefits and costs of prospective investments through all their possible economic ramifications.[20] As discussed elsewhere in the Primer, newly emerging research indicates that major network improvements can lead firms to restructure production processes and logistics and thereby generate substantial productivity gains that are not measured under traditional approaches. In examining past changes in productivity in relation to infrastructure investment, and in doing so for either the national or a regional economy overall, indicative planning techniques attempt to measure all productivity impacts in full.

Disadvantages of Indicative Planning Methodologies

There are a number of important disadvantages with indicative planning methodologies. Depreciation and serviceability methods make the implicit assumption that what was appropriate in the past remains appropriate for the future -- a highly speculative assumption.

Macroeconomic studies moreover are subject to a great deal of both theoretical debate and pragmatic uncertainty. Studies using the same data produce different elasticity estimates and thus imply different indicative targets. Experiments conducted by the Brookings Institution[21] find that the Aschauer-Munnell results, for example, are sensitive to variation in key underlying assumptions; in one test, the estimated elasticity of productivity with respect to infrastructure investment (other things being equal) fell below 0.1 (less than one-third the Aschauer-Munnell finding) and its statistical significance declined. This variability has led one prominent economist to conclude that, "This type of macroeconomic analysis yields results that are not sufficiently precise to be useful for policy analysis."[22]

It should be noted, however, that the extremely high returns to public investment implied in the Aschauer-Munnell indicative analysis (in excess of 140 percent, with pay-back periods of less than a year -- see above) find support in evidence from the appraisal of individual projects. Findings reported elsewhere in the Primer indicate that current investment opportunities designed to relieve highly congested airport and highway conditions can yield expected returns in excess of 100 percent and pay-back periods of as little as one year. These seemingly startling returns at the project level simply indicate that investments have been delayed while demand continued to rise. Delay in the implementation of economically worthwhile investments promoted growth in congestion, growth which is known to follow an exponentially rising pattern. Since reduced congestion and increased system reliability represent the underlying basis for investment-related economic benefits, the advent of expontially growing congestion means that it is actually not

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[20] In fact, economists refer to such techniques as "partial equilibrium" methods, meaning that they measure the balance between the benefits and costs of prospective investments without attempting to trace all their effects throughout the economy.

[21] Henry J. Aaron et. al., **Comments on "Why Infrastructure is Important?" by David A. Aschauer.**

[22] Dale W. L, **Fragile Statistical Foundations: The Macroeconomics of Public Infrastructure Investment**, Harvard University, February 1991.

surprising at all to find projects with extremely high returns and fast pay-back periods. Long delays in profitable private sector investments, in the face of rapidly growing market demands, yield precisely the same result.

At the same time, however, executives and decision makers should note that returns to current investment opportunities do not yield rates of return of more than 100 percent *on average*; while such projects are not unusual, most "good" infrastructure investment opportunities yield returns of 20 percent to 60 percent, high but suggestive that the Aschauer-Munnell findings are too high as an indicative target. This conclusion finds support in other macroeconomic studies of this kind.[23]

Other disadvantages with indicative planning methodologies lie in the nature of indicative planning itself. Some analysts argue that even if we knew the extent to which past investment contributed to economic growth, we would be far from knowing how much we should be spending now, and on what we should spending it. While the application of indicative planning methodologies can help executives identify gross under- or over-investment levels from a budgetary perspective, only the application of forward-looking methodologies can identify the most promising investments and distinguish strong from weak transportation program and project choices. As well, the application of indicative planning methodologies offers no information about the extent to which existing systems and facilities can be made more productive without major capital investment. The Congressional Budget Office, for example, worries that simply spending more will bypass such opportunities.[24]

There can be no doubt, therefore, that indicative planning methodologies, while useful as an indicative budgeting guide, cannot substitute for the continuous search for productive investments and the careful analysis of specific alternatives as a basis for decision. The strategic principles of forward-looking investment choice methodologies are examined next.

INVESTMENT CHOICE METHODOLOGIES

To ensure the provision of appropriate information for selecting specific investment programs and projects, executives should help establish three key components of a methodological strategy:

- The Decision Criteria;
- The Principal and Secondary Methodological Approaches; and
- The Methodological Techniques and Procedures.

The order above is important. Decision criteria flow directly from objectives; the appropriate

[23] Dale W. L, **Fragile Statistical Foundations: The Macroeconomics of Public Infrastructure Investment**, Harvard University, February 1991.

[24] See W. David Montgomery, **Lessons from the Past, Opportunities for the Future: The Changing Role of Public Transportation in Economic Growth**, Remarks to the Colloquium on the Nation's Infrastructure Policy, November 17, 1989, Washington DC

methodological approach depends upon the selected decision criteria; and fitting techniques and procedures hinge on the choice of methodological approach. Choosing a technique without reference to objectives and decision criteria means that the information available to decision makers will likely be irrelevant -- or at best indirectly related -- to the issues at-hand.[25]

Choosing the Decision Criteria: The Critical Strategic Step in Devising a Methodology
A "decision criterion" is simply a yardstick against which to gauge the performance of transportation policies and investments (whether proposed or existing) in achieving their objectives. In light of the executive's accountability for providing pertinent information to decision makers, involvement in the choice of decision criteria is by far his or her most important function in the development of a methodological strategy.

As shown in Table 2, the choice of decision criteria is directly related to decision makers' policy objectives. Two key principles are reflected in Table 2:

- The achievement of economic growth-related objectives can only be measured against the yardstick of rate of return. Rate of return principles should be applied in deciding both *whether* to invest and *when* to invest;

- The achievement of distributional objectives can only be measured in terms of *increases* in regional economic activity.

The Rate of Return Principle. Whether growth is defined in terms of productivity, gross output or economic welfare and living standards, it can only occur if more of value is put into the economy than is taken out (spent) in order to achieve it. Only by gauging transportation policies and investments in terms of their rate-of-return and net present value can decision makers discern their implications for productivity and economic growth.

The evaluation of public investment in the context of economic growth does not, in essence, ask a different sort of question from that posed by a private enterprise in pondering the wisdom of a proposed investment. But while the company analyst asks whether its owners will be made better off by the proposed investment -- whether they will enjoy a rate of return greater than that to be earned from alternative uses of the money (including that of leaving it in the bank) -- the state or local transportation analyst needs to ask whether the economy as whole will be made better off by undertaking the project rather than not undertaking it, or by undertaking an alternative project instead.

Public and private rate of return calculations differ principally in the range of costs and benefits taken into consideration. The corporate executive is interested only in those costs and benefits that effect shareholder returns, namely those expected to accrue to the firm. The public sector transportation executive, by contrast, must view all costs and benefits as germaine to the

[25] The application of a given technique or procedure without explicit consideration of objectives and decision criteria involves an implicit value judgement as to what policy objectives **ought** to apply. Where policy and decision makers are elected officials, this practice runs contrary to normal democratic principles under which elected representatives establish social and economic objectives and executives provide information regarding alternative means of achieving them.

TABLE 2:
SUMMARY OF ALTERNATIVE INVESTMENT CHOICE METHODOLOGIES

Focus of Objectives	Methodology		
Growth	**Decision Criterion**	**Principal Approach**	**Supplementary Approach**
Productivity	Rate of return above the average return on investment in the private sector	Benefit-Cost Analysis with scope restrictions	Incremental Impact Analysis
Output	Positive rate of return	Benefit-Cost Analysis with scope restrictions	Incremental Impact Analysis
Welfare and Living Standards	Rate of return greater than social opportunity cost of capital	Benefit-Cost Analysis	Incremental Impact Analysis
	Alternatives ranked according to net present value		
Distribution			
Employment	Increased employment in the State or specified locality	Incremental Economic Impact Analysis	Regional Economic Base Analysis
Personal Income	Increased wages and salaries in the State or specified locality	Incremental Economic Impact Analysis	Regional Economic Base Analysis
Regional Output	Increased value of goods and services produced in the State or specified locality	Incremental Economic Impact Analysis	Regional Economic Base Analysis
Sectoral Output	Increased value of output in a specified industry sector	Incremental Sectoral Analysis	Sectoral Economic Base Analysis

[1]Supplementary approaches pertain only indirectly.

calculation of return on investment, not just those which directly effect his particular responsibility area -- the shareholders are, in effect, the public at-large.

> This above distinction between public and private rate of return calculations has two practical implications for transportation executives. First, impacts beyond those of direct consequence to the executive's responsibility area must be examined. For example, in addition to changes in the structural sufficiency of pavement expected to result from a proposed road improvement program, the highway executive needs to examine the proposal's monetary implications for vehicle operating costs and time savings, both in relation to the capital expense and future maintenance costs associated with the proposal.

A second implication is that the impacts of transportation investments on parties other than users of the transportation system need to be taken into account. Executives usually encounter environmental and noise impacts in this context. Accounting for the negative "spillovers" in rate of return calculations ensures that transportation-related productivity and growth strategies are not at odds with the higher aim of improved living standards. With these two modifications to the traditional rate of return principle, transportation executives can use rate of return as an index of transportation's contribution to productivity, economic growth and the standard of living.

How do Returns to Transportation Investment Translate into Productivity and Returns for the Economy at-Large? Transportation officials often ask how it is that the traditionally quantified benefits of transportation investments, namely reduced vehicle operating costs and user delay, translate into productivity gains for the economy at-large. Stated differently, this question asks whether social rate of return, measured according to the principles outlined above, actually mirrors the true economic returns of transportation to the economy. The answer is "yes." This is because the monetary value of savings in vehicle costs and travel time have consequential benefits in the form of improved business and industrial productivity. Time savings for business travellers mean more hours of productive work; faster deliveries to factories and thus more output per hour; less fuel consumption per hour of productive work; and an enormous range of other ways in which business and industry translate transportation improvements into higher hourly production.

There are, to be sure, important technical problems to be overcome in making rate of return calculations as accurate an index of productivity and growth as possible. Statutory limits on drivers' hours in freight distribution, for example, mean that some of the potential time savings from a network improvement may not be translated into productivity gains. As discussed in Chapter 6, this can require adjustments in the "value of time" assumption to avoid overstating potential benefits. On the other hand, new research in the area of distribution logistics indicates that firms will find any and all means of capturing the advantages of transportation improvements. They might, for example, reduce inventories and the number of depots in such a way that the same distribution territory can be served, with the same total travel time and within required delivery schedules, because of the improved highway conditions. In this example, the firm captures productivity gains from a transportation improvement in the form of lower overhead rather than reduced travel time; the traditional measure of benefit -- namely potential travel time reductions -- can thus understate actual productivity gains. The general point however is that, with modifications to account for previously unmeasured productivity implications of transportation, benefits as traditionally measured and reflected in rate of return calculations provide a good index of infrastructure's productivity and growth implications for the economy.

Can Decisions Based on Social Rate of Return Cause Reduced Economic Performance and Competitiveness? The answer to this question is "no" -- provided that decision makers are prepared to go beyond a mere short-term view of economic performance. To be sure, instances can be imagined under which a positive social rate of return means less rather than more GNP or regional output from an immediate accounting viewpoint. Transportation-related externalities - - benefits and costs that do not translate directly and immediately into either increased or decreased output -- include environmental costs such as aircraft and highway noise and safety-related benefits stemming from reduced accident rates. If a project achieves a positive social rate of return because external benefits exceed internal (ie, GNP-related) costs, the immediate impact from an accounting viewpoint could be a decline in GNP (albeit an increase in general economic welfare). This could occur where, for example, safety or reduced emissions represent a project's sole benefit. Such situations are likely to be rare, however, since most transportation benefits (particularly time savings) translate eventually, whether directly or indirectly, into improved GNP. Time savings and reduced accident rates, which together typically account for more than 80 percent of transportation benefits, ultimately mean fewer losses in working time, thus raising productivity and total output.

What about decisions to reject policies with negative social rates of return even though GNP would be increased -- are such decisions misguided from the viewpoint of economic competitiveness? Here again, most external costs that cause a negative social return would ultimately, if not immediately, cause reductions in output and competitiveness. The economic cost of increased aircraft noise would ultimately be paid for in fewer housing starts, for example, thereby reducing output in the longer term. Diminished air quality would ultimately be paid for in the form of less efficient production of goods and services because of mitigation requirements. All-in-all, the use of social rate of return as a basis for decisions is consistent with both social and economic objectives.

In practice, the rate of return principle should be applied to establish both whether a policy or investment proposal promotes productivity and growth and *when* the economically appropriate time to invest occurs.

Whether to Invest. Translating Rate of Return into Net Present Value as Criterion of Productivity. The rate of return test permits decision makers to discern whether transportation policies and investments make a worthwhile contribution to productivity and economic growth. This requires the use of a procedure (called "discounting" -- see Chapter 8 for details) under which the minimum-required rate of return -- such as the social opportunity cost of capital -- is used to align all forecasts of a proposal's costs and benefits to a common basis of comparison. This is accomplished by computing their equivalent present-day values, a procedure designed to compensate for the fact that different policies produce costs and benefits at different rates over their service lives. The present value of the costs is then subtracted from the present value of the benefits, resulting in the *net present value.* As shown in Table 3, there is a direct, simple relationship between rate of return and net present value. Although one is as good as the other in assessing a single investment proposal, net present value is the appropriate yardstick for comparing the economic merits of alternatives.

If the net present value of a prospective policy or investment is greater than zero -- and assuming that it is forecast correctly -- it may be considered a worthwhile contribution to productivity and well worth funding (for it means that the minimum-required rate of return is assured). The net present value criterion also permits alternative policies and investments to be ranked in order of merit. Policies and programs with higher net present values promote more productivity and growth than those with lower results. Due to certain mathematical anomalies that can arise in the use of rate of return to rank alternatives, the executive should always insist that policy and investment proposals be presented in terms of their estimated net present values.

Ranking Alternatives According to Net Present Value When Capital Budgets are Highly Limited. Traditional economic thinking counsels that any project with a positive net present value should be undertaken. If a $500 million project yields and NPV of just $1.00, the theory dictates that it should be undertaken because the $500 million earns one dollar more for society than it would in its next best application. This reasoning assumes, however, that states and localities have unlimited capital resources and that they are free to transfer capital between sectors. When programs or projects with positive NPVs must be rejected or delayed for budgetary rather than economic reasons, the executive's task is to find those investments that yield the greatest productive value per dollar of capital invested. One useful method of rationing capital under such circumstances is to rank investment choices according to an index formed by the net present value divided by the total capital cost (the latter expressed in terms of present value). This "bang for the buck" criterion ranks alternatives according to the net benefit they are expected to yield per dollar of capital invested -- a measure of the estimated value to be obtained from limited capital funds. This is an especially useful test.

In addition to net present value, there are other popular measures that provide interesting supplemental growth-related information for use in decision making. As shown in Table 3, the "internal rate of return" indicates the *extent to which* the expected return on investment exceeds or falls short of the minimum-required rate of return and thus provides insight into project risk. The Benefit-Cost Ratio indicates the dollars of benefit generated by the policy or investment in question for each dollar cost. While these indicators provide decision makers with additional useful information, only net present value may be regarded as the basis for establishing, categorically, whether or not a prospective investment is economically worthwhile (see Box 4).

Net Present Value Versus Sufficiency Ratings and Cost-Effectiveness Analysis as a Basis for Infrastructure Decision Making. Many states, localities, transportation authorities (and the federal government) use pavement sufficiency ratings, volume-to-capacity criteria and various forms of cost-effectiveness analysis to judge the merits of alternative investment policies, programs and projects. The executive thus needs to know whether these approaches will lead decision makers to the most economically productive projects.

All the evidence, both theoretical and actual experience, indicates that sufficiency ratings, volume-to-capacity criteria and cost-effectiveness tests do a poor job of helping decision makers find the most economically worthwhile transportation policies and projects. Where the economic aims of transportation policies include diminished vehicle operating costs, reduced congestion and delay, enhanced safety and environmental conditions and stronger business and industrial productivity, net present value leads to different and substantially better investment decisions than sufficiency ratings or cost-effectiveness analysis.

The Highway Case. Highway sufficiency ratings -- engineering standards used to evaluate the structural, safety and level of service attributes of roadways -- are used by most states to rank construction projects. As well, the Federal Highway Administration and a number of states have devised cost-effectiveness tests as a basis for decision making. These tests are typically measured by the capital cost of a proposed improvement divided by the projected change in sufficiency

TABLE 3:
KEY MEASURES OF PRODUCTIVITY AND ECONOMIC GROWTH

Measure of Worth	**Definition**	**Interpretation**
Net Present Value	Present-day value of benefits minus present-day value of costs.	NPV greater than zero means project is economically efficient Projects are ranked according to NPV.
Rate of Return	The discount rate at which NPV=0	Rate of return should exceed pre-set hurdle rate to qualify for consideration.
Benefit-Cost Ratio	Present value of benefits divided by the present value of costs. Indicates dollars of benefit per $1.00 of cost.	A ratio of greater than one means the project is worthwhile.
Measures of Timing		
First-Year Benefit	Benefits in the first year after construction divided by costs to date including interest paid during construction, expressed as a percent.	A ratio equal to the hurdle rate (10%) means the project is optimally timed. A ratio below the hurdle rate means the project is premature. A ratio above the hurdle rate means the project is overdue.
Pay-Back Period	Number of years until capital recouped through through the flow of benefits.	A short pay-back period means less risk.

BOX 4

CASE STUDY

**TRANSPORTATION, PRODUCTIVITY AND OVERDUE INVESTMENT:
The Use of Rate of Return; Net Present Value; and First-Year Benefit Tests**

In 1982, the Federal Aviation Administration formulated a $24 billion plan to modernize the nation's air traffic control system. Through automation, the Plan would increase capacity to handle traffic, diminish risks of mid-air collision and other hazards, and shorten flight times by allowing aircraft to follow more direct routes. Facility consolidation and staff reductions from automation would increase productivity and reduce operating and maintenance costs.

Rate of Return

On the basis of these benefit and cost projections, the CBO calculated that the annual rate of return to be expected from the FAA plan over the two decades is 24.3 percent -- a healthy return by any standard (see Summary Table). Indeed, measured against the commonly used if somewhat arbitrary standard of 10 percent set by the Office of Management and Budget (OMB) for federal investment, it was concluded that the FAA plan is likely to offer very good value.

CBO noted that another useful guide to the economic value of a capital project is the present value of the expected benefits minus the costs (net present value). Using 10 percent rate of return to adjust future costs and benefits to their present-day values, the benefits of the FAA plan were estimated to exceed its costs by $9.1 billion in net productivity gains.

	Return on Investment			**Timing**
Forecasts	Rate of Return (In percents)	Benefit-to-Cost Ratio a/	Benefits Minus Costs (In billions of dollars) *Net Present Value*	Return in the First Year after Completion (In percents)
Under FAA Assumptions	24.3	2.3:1	9.1	14.9
Under Lower Traffic Forecast Scenario	21.3	2.0:1	6.8	13.1

SOURCE: Congressional Budget Office.

a. Benefits and costs are discounted to their 1982 values at the annual rate of 10 percent.

Timing and Identification of Overdue Investments

The Congressional analysis also looked closely at the project's timing from the viewpoint of productivity and economic growth. Using the First-Year Benefit ratio, the study concluded that since the return in the first year after project completion was likely to *exceed* the minimum-required rate of return, automation of the system was actually overdue.

The recent application of this test of infrastructure investment timing to airport expansion projects at Vancouver and Minneapolis-St. Paul indicate that these investments are each more than 10 years overdue (First-Year Benefit Ratios in each case exceed 100 percent, more than ten-times the 10 percent minimum-required annual rate of return set for these investments.

In the case of the air traffic control system and that of airport expansion in Minneapolis-St. Paul, evidence about timing strongly influenced decisions to undertake large-scale investments.

rating. In some cases, the sufficiency rating is first multiplied by the annual average daily traffic over the roadway in question in order to favor improvements to heavily travelled over lightly travelled roads. A few states use discounted life-cycle cost in forming the cost-effectiveness ratio (capital costs and plus maintenance costs expected to be incurred in each year of a project's estimated life, all expressed in the present day equivalent and then divided by the sufficiency rating).

Economic theory predicts that the benefits of roadway and network improvements will be greater (maximized, in fact) if net present value is used instead of sufficiency ratings and cost-effectiveness tests as a basis for decision.[26] This has been confirmed in tests of actual projects conducted by the Texas Transportation Institute (TTI).[27] The TTI concludes that, faced with a budget limitation, the net present value test guides decision makers to projects with significantly greater highway benefits than those arising under other criteria. This means that more vehicle cost savings, reductions in delay, safety and environmental benefits and business and industrial productivity gains will be achieved if decisions are guided by the net present value criterion as compared with the application of sufficiency ratings or cost-effectiveness tests (see Box 5).

An advantage of the sufficiency rating and cost-effectiveness approaches is their broad acceptance in the highway planning community. It is clear however that the use of these approaches for investment decision making causes a major sacrifice in the economic benefits to be drawn from transportation infrastructure and in the contribution of transportation investment to productivity and economic growth. Executives should thus insist upon the availability of net present value information as part of the highway investment decision making process.

The Transit Case. The net present value criterion has also been found to be the only reliable test of economic performance in other aspects of transportation infrastructure. In theoretical tests, the London School of Economics has concluded that sizeable reductions in welfare and economic living standards can result from the use of cost-effectiveness tests in lieu of net present value maximization in transit decision making.[28]

Tests with actual projects (see Box 6) confirm that cost-effectiveness tests can deter decision makers from choosing transit projects with the highest potential contribution to productivity and economic growth.

The Airport Case. Many airport authorities use volume-to-capacity criteria to make judgements about the need for runway, taxiway, terminal, parking and other capital investment decisions. Here the evidence mirrors that of the highway and transit cases. Volume-to-capacity criteria are necessarily arbitrary, indicating nothing about whether or when new investment is economically worthwhile. Case studies conducted in the 1990 Survey of Current Practice demonstrate that volume-to-capacity tests in practice tend to understate the level of desirable investment and fail

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[26] See, Stephen Glaister, **Fundamentals of Transport Economics,** Basil Blackwell - Oxford, 1981.

[27] William F. McFarland, **Ranking Highway Construction Projects: Comparison of Benefit-Cost Analysis with Other Techniques,** Texas Transportation Institute (Paper presented at the 68th Annual Meeting, Transportation Research Board, Washington DC, January 1987).

[28] Stephen Glaister, (ibid).

BOX 5

CASE STUDY

Net Present Value versus Sufficiency Ratings and Cost-Effectiveness Analysis as a Basis for Highway Investment Decisions

The Texas Transportation Institute compared three techniques for ranking and selecting highway construction projects under a budget constraint. Benefit-Cost Analysis was used to estimate net present values for 1,942 capacity-related projects. Sufficiency ratings and cost-effectiveness tests were also developed and all projects were ranked accordingly.

The net present value criterion was found to guide decision makers to better and more economically sound highway projects than either of the other two approaches. The table below reports cumulative estimated benefits in the form of vehicle cost savings; time savings; safety and environmental benefits; and business and industrial productivity gains. For a ten-year budget of $5.7 billion, decisions based on the Net Present Value procedure yield over $22 billion more benefits than decisions based upon the sufficiency rating and some $7.8 billion more than the cost-effectiveness approach.

Cumulative Highway Improvement Benefits as Selected Budget Levels, by Decision Criterion

Ranking and Decision Criterion	Cumulative Benefits ($ Billion) for Cumulative Cost of:		
	$0.785 Billion (One-Year Program)	$3.551 Billion (Five-Year Program)	$5.742 Billion (Ten-Year Program)
Texas Sufficiency Rating	$ 7.316	$ 24.610	$ 36.512
Texas Cost Effectiveness	12.980	39.034	51.618
Net Present Value	16.780	45.723	59.202

SOURCE: Texas Transportation Institute, 1987

BOX 6

CASE STUDY

Net Present Value versus Cost-Effectiveness Analysis as a Basis for Transit Investment Decisions

Many transit authorities, as well as the federal government, use cost-effectiveness tests to help guide investment decisions. Tests such as cost per new-rider in help is the search for investments that maximize the number of travellers attracted to transit for each dollar spent on facilities and services. Such tests do not, however, indicate which alternatives offer the highest net economic returns nor whether the economic benefits of transit projects, such as time savings and environmental gains, outweigh their costs and thus contribute to productivity and economic growth.

Tests conducted in preparing the Primer confirm that cost-effectiveness and net present value tests can yield very different economic signals to decision makers. The Case Study reported in the Table below indicates that, for the city in question, the cost-effectiveness test favors a light rail option whereas the net present value criterion indicates that an express bus approach is likely to yield a higher net economic benefit.

The Table also indicates a risk that none of the options considered are likely to yield benefits in excess of costs (all net present values being negative). This information would be unavailable with only cost-effectiveness information.

Like any forecast, however, net present values should be viewed in the context of sensitivity and risk analysis. Express Bus Option Two, for example, produces an NPV near zero, indicating a broadly satisfactory rate of return. As well, a longer assumed life for each of the options shows that the Light Rail Two alternative is likely to yield a positive Net Present Value. The Express Bus Option Two, however, remains the most economically attractive from an economic perspective.

Economic Benefits of Alternative Transit Improvements in a Selected Urban Area, by Alternative Decision Criteria

Alternative	Cost-Effectiveness (Cost Per New Rider)	Net Present Value (Millions)
Transportation System Management	$ 3.71	-$ 5.60
Express Bus Option One	$18.18	-$16.40
Express Bus Option Two	$ 3.12	-$ 0.30
Light Rail Option One	$ 5.86	-$46.90
Light Rail Option Two	$ 2.87	-$ 8.60

to reveal the urgency of investment opportunities from the perspective of their contribution to productivity and growth. The question of the proper timing investments is discussed more fully next.

When to Invest. Net Present Value and the First-Year Benefit Ratio as an Index of Optimal Timing. Though critical to economic success, the right timing for policies and investments is often overlooked in transportation investment planning. Since productivity benefits, such as fuel and time savings, often increase over time as traffic levels grow, an investment that appears worthwhile overall may draw principally on distant forecasts in order to display a strong net present value. In the early years, such projects often display very poor rates of return, to be off-set by stronger returns later on. The construction of Dulles International Airport near Washington DC is a case in point. Though clearly a highly productive investment, Dulles did not begin to generate reasonable returns until 15 years after its construction. In such cases, it is economically worthwhile to hold-off implementation until the rate of return is expected to achieve minimum-requirements in the nearer term, thereby liberating capital dollars for more productive policies and investments, investments that stimulate more rapid growth in the meantime.

As shown in Table 3, the *First-Year Benefit* test provides an unambiguous check on whether the proposed timing of a policy or investment is economically sensible in terms of net present value. Executives need to be aware that the optimum year in which to commission an investment is the start-date that maximizes its net present value. Net present value can be shown to be maximized when the benefits in the first year after commissioning an investment, divided by the total costs incurred to that date (including interest), is equal to the minimum-required rate of return. If this ratio -- called the *first-year benefit ratio* -- is less than the minimum-required rate of return, it means that delaying the project would increase its net present value. On the other hand, if the first-year benefit ratio is more than the minimum-required rate of return, the policy or investment may be said to be overdue (see Box 4).

The application of this test to recent major transportation investment proposals in Minneapolis-St. Paul, Vancouver, British Columbia, the federal Air Traffic Control System and others indicate that a great many infrastructure investments are significantly overdue from the viewpoint of maximizing the rate of growth (both regionally and nationally) in productivity, output and living standards. Many projects display projected rates of return in their first year of operation in excess of 100 percent. By comparison, a recent macroeconomic analysis[29] indicates that infrastructure investment is dramatically more important in determining aggregate productivity in the economy than is other forms of investment, both private and public.

The study attributes this result to the decline in public relative to private investment over the past 20 years which in turn has created greater potential returns from the former. The strong evidence of higher rates of return and long-overdue investments at the program and project level give weight to this finding.

Other measures of timing -- such as the number of years an investment needs to break-even (i.e., for the value of productivity gains to match the investment cost) -- provide useful information for decision makers. The faster they pay-back the less reliant the investment's return is upon relatively distant and uncertain forecasts. This is obviously an attractive trait of any prospective

[29] David Aschauer, **Is Public Expenditure Productive**, Journal of Monetary Economics, ibid.

investment but, again, optimality requires the maximization of net present value.

Increased Regional Economic Activity and the "Incrementality" Test. Whether desired regional economic impacts are defined in terms of employment, income, output or the activity of specific industry sectors, they can only be counted towards the achievement of distributional objectives if they would not have accrued to the regional economy *in the absence* of the policy or investment under review. Economic impacts must represent *incremental* gains and not just shifts in the composition of employment and output.

Incremental gains can occur only if there is long-term structural unemployment in the local economy *and* if alternative uses of the capital dollars would create less economic impact than the proposals under review. Without this test of "incrementality" the employment and income impact of a policy or investment in itself provides insufficient information for judging the achievement of distributional objectives.

Choosing Principal and Supplementary Methodological Approaches

A "methodological approach" is a family of related measurement techniques and procedures. They are related in the sense that each provides information of relevance to the same decision criterion.

"Principal" methodological approaches are those which must be applied in order to gauge the performance of proposed or existing transportation policies and investments.

"Supplementary" approaches, on the other hand, provide additional and related information of interest to decision makers; typically however they do not provide information of direct bearing on the decision criterion. Table 2 outlines the principal and supplementary methodological approaches associated with growth and distribution-related objectives and their associated decision criterion.

Principal Methodological Approaches in the Measurement of Growth-Related Objectives. The principal approach to be applied in evaluating the performance of policy and investment alternatives in achieving growth-related objectives is benefit-cost analysis. Only through the use of the various benefit-cost techniques and procedures can decision makers obtain the rate of return and net present value information they need to judge the productivity and growth potential of alternative policies and investments.

If productivity and gross output are to be viewed as ends in themselves, certain scope restrictions can be applied in the application of benefit-cost analysis. In seeking only to promote growth in output, for example, there is no need to value changes in safety, noise and other "intangibles" since these are not included in the conventional means of accounting for gross output. As noted earlier, however, the economic welfare and standard of living of state and local residents represents the "bottom line" for decision makers in virtually all situations and benefit-cost analysis provides categorical estimates the appropriate decision criteria, namely net present value, rate of return and optimal project timing.

Why is it that the techniques of Incremental Impact Analysis should not be used in establishing the economic growth implications of policies and investments? Although this family of approaches can provide projections of net growth in employment, income and economic output in association with transportation policies and investments, the fact that they include only conventional accounting definitions of goods and services means that fundamental gains and losses associated specifically with transportation infrastructure are omitted from the analysis. These include productivity gains associated with time savings, safety benefits and lowered vehicle operating costs and potential costs due to environmental impacts.

In addition, most conventional applications of incremental impact analysis (such as Input-Output Analysis -- see below) provide estimated impacts at a single point in time; this means that no allowance can be made for the time-phasing of costs and benefits -- perhaps the most critical aspect of a rate of return and net present value analysis. Finally, incremental impact analysis, most notably Input-Output techniques, typically assume no structural change in the productivity of individual industries and firms as a result of transportation policies. It is now known, however, that firms may restructure their production technologies in response to transportation improvements by, for example, reducing inventories or even eliminating storage depots in response to more reliable highway networks.

Serious efforts have been underway, in some cases for many years, to expand incremental impact analysis so as to accommodate social and environmental factors, time phasing and productivity changes in firms and industries.[30] Such attempts lead to extremely complex and costly models whose results are nevertheless too general to address the economic rate of return associated with specific transportation policies, even at the system level.[31]

Supplementary Methodological Approaches in the Measurement of Growth-Related Objectives. Measures of net present value indicate whether or not a policy or investment is likely to yield gains in productivity, output and living standards. In arriving at the net present value estimate, benefit-cost analysis provides information about the nature of the economic costs and benefits associated with the investment, such as reduced delay, savings in vehicle operating costs and safety and environmental impacts. Reductions in transportation costs, however, will have implications for employment, income and output and this level of detail is not revealed by benefit-cost analysis alone.

The various applications of incremental impact analysis represent the appropriate methodological approach to obtaining information about particular ramifications of alternative policies. In particular, they can provide decision makers with important details regarding the re-distributional implications of any growth associated with the policies and investments under review; who gains and who loses will often be the basis for choosing between one policy or investment and another.

Information from incremental impact analysis can include changes in regional commodity flows, incremental employment and income impacts and increased land values associated with transportation improvements. Since policy objectives will usually reflect both growth-related

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30 See, Barbara R. Bergmann, **Assessing the Impact of Alternative Economic Outcomes on Social Objectives**, (in) **Input-Output Techniques**, North-Holland Publishing Co., 1972.

31 For a review of recent innovations see, Apogee Research Inc., **Current Literature on Highway Investment and Economic Development**, Federal Highway Administration, October, 1989 For a technical overview and literature review see, William F. McFarland and others, **Economic Analysis of Transportation Expenditures; A Literature Review** Federal Highway Administration, November, 1989 (Draft) 147 References.

concerns and specific regional issues as well, this level of detail can be of great importance in the decision making process.

It must be understood however that it will rarely be the case that the value of employment and income gains can be added to the reduction in transport costs and other economic benefits identified in the benefit-cost analysis; this would usually represent double-counting since it is these benefits that give rise to the employment and income gains. In other words, the reduction in transport costs is eventually transposed into employment, income and other gains, the precise effects dependent upon the supply and demand for the thousands of commodities and services that are traded in the economy everyday. Incremental impact analysis techniques permit these transpositions to be explored.

Principal and Supplementary Methodological Approaches in the Measurement of Distribution-Related Objectives. As shown in Table 2, the family of tools and procedures known collectively as incremental impact analysis provides the principal means of measuring the performance of policies and investments in promoting regional gains in employment, income and other distributional aims.

Supplementary information in the measurement of distributional aims is generated by a family of techniques and procedures called Regional Economic Base Analysis. This approach uses the same basic techniques and procedures as those employed in incremental impact analysis; they differ in that they do not provide a test of incrementality. Rather, they provide a "snap-shot" estimate of the employment, income and industry composition associated with a given policy or investment. Examples include the popular "Economic Impact Studies" often used to publicize the economic role of a facility as an employer and generator of economic activity in the regional economy. While these studies provide useful context for decision makers, they offer no practical evidence of the distributional changes associated with policy or investment initiatives.

Choosing Among Alternative Techniques and Procedures

Unlike the choice of decision criteria and broad methodological approaches, both of which require in-depth executive involvement, the ultimate mix of specific techniques and procedures rests more with practioners than with executives and decision makers.

From the executive's perspective, however, the various techniques and procedures within a given methodological approach can usefully be distinguished in terms of their complexity, data requirements, cost and reliability and questions can be asked to ensure the choice of cost-effective package of approaches.

The key techniques and procedures in each broad methodological approach are shown in Table 4, together with an assessment of their relative complexity, cost and reliability. An overview is provided below; further details are presented in subsequent chapters devoted to key methodological issues.

Benefit-Cost Analysis. Conventional approaches to benefit-cost analysis are moderate in cost and highly reliable, especially when combined with techniques of risk analysis (see Chapter 9). The conventional approach to measuring the benefits of infrastructure investment is to estimate the direct cost savings to current users, and add an additional allowance for the benefits of increased infrastructure use caused by the lowered costs.

Direct costs, both capital and operating, are counted as cash flows. Other, so-called "external costs" -- such as aircraft noise and air pollution -- are estimated by various techniques and procedures depending upon the policy or investment under review (see Chapter 7).

The underlying assumption of the conventional approach is that production and distribution technologies and patterns of infrastructure use will remain largely the same, except for expansion of infrastructure use as a result of the new investment.

However, theoretical and applied research conducted for the Primer indicates that the conventional approach is incomplete. Specifically, it makes no allowance for private sector productivity gains from restructuring that may be enabled by infrastructure investment. Such restructuring can include reduced company inventories in exchange for greater use of transportation systems; reduced stocking points (depots and so on); and the adoption of more efficient production-line technologies (such as just-in-time inventory).

Potential impacts of infrastructure investment thus remain unaccounted for in the conventional approach. Firms may reorganize their logistics and distribution networks as a result of road or airport improvements. The elimination of congestion and resulting improvement in the reliability of delivery schedules can enable firms to make smaller and more frequent deliveries (in order to reduce inventory and handling costs). Road improvements can permit larger vehicles in some areas, or reduce packaging requirements. Experimental evidence developed for the Primer (see Chapter 6) indicates that failure to account for restructuring impacts such as these in network-level benefit calculations can understate prospective rates of return by 25 percent to 120 percent.

While methods of accounting for such impacts are in their infancy, Chapter 6 explores possible avenues of approach.

Incremental Impact Analysis. Techniques and procedures of incremental impact analysis span a wide range of costs and levels of reliability.

Macroeconomic Models involve statistically determined equations that estimate key relationships in the economy. Both national and regional macroeconomic models are available. Such models can be used to estimate the effects of transportation expenditures on employment levels, income, output and other economic variables. The incrementality test can (and must) be applied in order to examine impacts of any given policy or investment.

An advantage of macroeconomic models is that they can be updated to account for changing economic relationships, a feature that enriches accuracy. A disadvantage is that models with equations that are sufficiently detailed to test detailed policy and investment proposals are expensive and highly complex. Complexity makes it difficult for executives and decision makers to explore their basic assumptions, thus creating uncertainty in decision making. A useful addition to overall policy making, the information from these techniques needs to be used with care.

Input-Output Models and Multiplier Analysis measure the interrelationships of marketed products and services among industries in either the national economy or in individual regional economies. The principal use of input-output models is to estimate how a change in economic activity, such as an increase in transportation investment, creates additional changes throughout the economy. Details regarding the commodity and financial flows between industries permit

TABLE 4:
SUMMARY OF METHODOLOGICAL TECHNIQUES AND PROCEDURES

Methodological Approach	Technique/ Procedure	Complexity	Data Requirements	Cost	Reliability
Benefit-Cost Analysis	Discounted cash flow	Low	Moderate	Low	Very High
	Valuation of non-cash impacts	Moderate	Moderate-High	Moderate	High
	Industrial restructuring analysis	High	High	Moderate-High	Experimental
	Risk Analysis	Moderate	Moderate	Moderate	Very High
Incremental Impact Analysis	Regional macroeconomic econometric models	Moderate-Very High	Moderate-Very High	Moderate	Moderate-High
	Regional input-output analysis	Very High	Very High	Very High	Experimental
	Regional multiplier analysis	Moderate-High	Moderate-High	Moderate-High	Moderate
	Investment-specific impact analysis	Moderate	High	Moderate-High	Moderate-High
	Land-use impact analysis	High		Moderate-High	Low
Economic Base Analysis	Regional input-output analysis	High	High	Moderate	Moderate-High
	Regional multiplier analysis	Low-Moderate	Moderate	Low-Moderate	Moderate-High
	Investment-specific impact analysis	Low	Moderate	Moderate	Moderate-High

[1]Executives should be aware that certain input-output applications remain experimental in nature. These include "computable general equilibrium" models and some models that attempt to incorporate social and environmental flows and changing properties over time.

input-output models to estimate the "multiplier effects" of such investments -- the extent to which new investment creates income, which in-turn is respent, creating yet more employment and business activity. The incrementality test can be applied by using the model both with and without the investment in question. A wide array of incremental economic impacts can be thus be estimated, including employment, personal income and gross output.

An advantage of input-output models is their ability to generate large amounts of detail on specific industry and sectoral impacts. A disadvantage is that most operational models offer economic detail only at a fixed point in time. This can be rectified with supplementary analysis using macroeconomic models.

An important disadvantage of input-output analysis is that the models are rarely developed in enough detail to analyze the economic impacts infrastructure investments in highly specific terms. Investment-specific impact analysis was developed to correct this shortcoming.

Investment-Specific Impact Analysis uses regional employment and output multipliers generated from input-output models but applies them specifically to the number of persons employed directly in association with the transportation system or project in question. The economic impact of a deep-water seaport, for example, would be seen to manifest itself in terms of:

- Jobs, both direct and induced;
- Personal income, including respending;
- Business revenue; and
- State and local taxes.

Recent applications have also realized increases in accuracy and detail by estimating the impacts outlined above individually for different sectors. At airports, for example, economic impacts have been estimated separately for concession businesses, airlines, travel agencies, taxi and limousine services and others. This is accomplished by supplementing broad regional multiplier estimates with detailed employment-to-sales ratios in each sector.

The incrementality test can be conducted by developing the impact analysis twice -- once for a base case in which no new investment occurs and again with expansion of the facility in question. Expansion brings with it increased traffic; the incrementality test is intended to establish whether the corresponding increase in economic activity is likely to yield net gains in employment and output in the regional economy. The incrementality test thus requires a careful specification and forecast of structurally unemployed or under-employed resources in sectors of the economy that employ individuals with skills like those required in each sector. In this way, it can be determined whether the economic impacts associated with facility investment are or are not incremental to the economy.

Executives should note that while the investment-specific impact analysis has become very popular, it is rarely implemented with the incrementality test (see Box 4 for an example of the incrementality test in application). Without this test, the results cannot be used to draw any conclusions about the distributional implications of the investment.

A disadvantage of investment-specific impact analysis is that each facility and investment must be analyzed as a unique entity -- the standard input-output "kit" cannot be applied. On the other hand, the analysis can typically be conducted at reasonable cost and the increase in detail, accuracy and degree of exposure in terms of underlying assumptions makes this a very cost-effective procedure. As well, methods have been developed that combine the approach with risk analysis, lending even greater credibility to the findings and increasing the confidence of decision makers.[32]

Land-Use Impact Analysis represents what is probably the most difficult and complex aspect of transportation research. On the other hand, transportation investment has been shown to have its most important economic impact on productivity and economic growth; the value of productivity and growth impacts will be "capitalized" into increased land values that stem from transportation improvements. Frequently, therefore, executives should not need to insist on both a benefit-cost assessment *and* a specific land-use evaluation. Exceptions apply where an investment is expected to create real economic gains or losses for land-holders, such as the effect of additional noise from a new runway or highway on nearby homes. These effects, which can be estimated with statistical techniques and surveys, need to be incorporated into benefit-cost assessments in order to gain a full appreciation of the economic standard of living implications of transportation policies and investments.

In situations where prospective land-use impacts are of specific concern, there is a wide range of techniques and procedures available to forecast them. Two classes of approach have been identified, namely (i) land-use and land-value measurement techniques and (ii) land use-traffic/urban development models.[33] Each involves a mix of statistical and survey-based measurement techniques typically with uncertain results.

A HYBRID STRATEGY OF INVESTMENT-CHOICE AND INDICATIVE PLANNING

Although techniques are emerging that will enable practioners of benefit-cost analysis to expand the range of productivity-related benefits identified in association with major transportation proposals, such techniques are certainly in their infancy and their accuracy and completeness will take time to refine and assess. This means that for major network improvements, there will be some concern that the sum of all infrastructure projects approved according to conventional approaches to rate of return and net present value maximization will fail to achieve the level and mix of transportation investments that maximize transportation's contribution to productivity and economic growth.

Moreover, since transportation infrastructure investments are long-lived, some of the major productivity impacts may not be presently foreseeable at all. Indeed, the revolution in just-in-time (JIT) production and distribution technology, and the enormous productivity gains that JIT

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32 See, Hickling Corporation, **The Economic Impact of Alternative Runway Improvement Possibilities for Lester B. Pearson International Airport, Toronto,** Transport Canada, October 1990.

33 See, William F. McFarland, ibid

has spurred, could not have been anticipated when the Interstate and primary highway systems were conceived and constructed. Yet the JIT revolution depends intimately upon the availability of these systems. Executives must thus bear in mind that investment choice techniques alone may fail to ensure the level of investment needed to promote the nation's return to a long-term growth rate in excess of 3.0 percent and stability in living standards.

At both the state and federal level, therefore, there is a call for indicative targets for infrastructure investment. To be sure, the establishment of targets should account for the pitfalls of indicative planning methodologies; in particular, capital spending towards the target should only be approved for programs and projects that demonstrably pass the rate of return test. Yet without a hybrid of indicative targets *and* careful application of investment choice techniques, newly emerging evidence indicates that the nation may under-invest from the viewpoint of economic growth.

There is, moreover, precedent for indicative planning in the approaches of our major industrial competitors. Japan and Germany, for example, both develop five-year infrastructure plans. These plans set aggregate spending levels and include breakdowns by geographic area, mode and "targeted" industries. In Germany's case, the five-year plan is set on a rolling basis. It is recast annually to look five years into the future. These infrastructure plans are part of a larger plan for growth.

At the federal level, Canada has developed an "envelope" system in which broad five-year capital investment targets are established on the basis of various indicative planning methodologies. Individual infrastructure investments, however, will only be approved if they pass the rate of return and net present value tests of benefit-cost analysis. Some Canadian provinces use a similar approach.

Setting State and Federal Indicative Targets

In the United States, both states and the federal government could each establish indicative planning targets based upon newly emerging methodological tools. It is important to note that indicative planning studies are very different from so-called "needs" studies. The latter are typically based upon sufficiency ratings, volume-to-capacity measures and other criteria that are actually (poor) substitutes for sound investment choice techniques (i.e., net present value) for selecting specific programs and projects. Indicative targets, in contrast, represent the estimated level of aggregate capital investment thought to maximize transportation's contribution to productivity. These targets could be used as a basis for establishing envelopes for capital budgets and authorizations. Under the hybrid approach, actual expenditures (appropriations) on specific programs and projects would require application of a sound investment choice test (i.e., minimum-required rate of return); the test could be stipulated in budgets and legislation along with the indicative target.

It is possible to establish indicative targets at the federal level as a roll up of indicative planning study results for each state. Such studies would need to be carefully controlled to ensure consistency of approach and might well represent an on-going process that would improve and prove its usefulness over time, perhaps as part of rolling budgetary process. If the federal government were to help finance such studies, it could also establish ground rules to guide their conduct. Methods of indicative planning for use at the state level are outlined next.

Methodologies for Establishing Indicative Targets

Under the hybrid approach, states (and the federal government) could conduct two kinds of indicative planning studies. First are those of a statistical nature akin to the studies of Aschauer and Munnell. A great deal of debate is taking place regarding the appropriate econometric tools to employ in such studies. Executives should ensure that all analyses are sensitive to the alternatives and that they are explored fully.

Second, and potentially much more useful, are indicative planning studies that assess the business and industrial productivity potential likely to be unlocked by major network improvements. These studies would use the Industrial Restructuring Analysis techniques and computer program developed for the Primer and presented in detail in Part III of the Technical Report (see also Annex A in the Primer). Although the application of Industrial restructuring analysis is forward-looking, the Technical Report recommends three kinds of *ex poste* industrial restructuring state-level studies as well. These are:

- Specific for each state, retrospective case study investigations of the impacts of past network improvements on actual firms' decisions to change production and distribution logistics and operations. These would be quantified using the methods and computer programs with the Primer to give meaningful estimates of the productivity impacts of actual projects;

- Specific for each state, development of a classification scheme of logistics and production/distribution technology improvements that can follow from transportation network investments. This scheme could follow from both the retrospective case studies suggested above and from direct case studies and interviews with firms. The classification scheme would be useful in a number of ways, including the conduct of panel sessions and the general search for productivity benefits associated with infrastructure improvements; and

- Specific for each state, development of a taxonomy of logistics and technology improvements classified according to the firms and industries in which such improvements can take place. This taxonomy would, in turn, be cross-classified with the infrastructure improvements that can help trigger such productivity impacts. This framework, developed on the basis of case studies and surveys (see above), would assist in the identification and quantification of potential productivity gains associated with prospective infrastructure improvements.

In summary, the use of statistical techniques would help states establish indicative targets that "learn" from general infrastructure impacts estimated to have occurred in the past; and the use of industrial restructuring analysis would help gauge the scope and design of network improvements likely to promote business and industrial productivity gains.

Together, executives and decision makers could forge overall spending targets that, while indicative only, provide executives and the specialists serving them with a powerful incentive to search for specific investments that generate net economic gains and thus gain access to the indicative investment envelope.

Under this hybrid approach, the importance of program and project-specific analysis remains extremely high; for only those specific programs and projects that pass the rate of return test would have drawing rights against the capital investment target (i.e., would be approved). The remainder of the Primer examines key issues in the search for productive and economically worthwhile investments.

PRIMER ON PROCEDURES AND TECHNIQUES

Although executives depend on technical experts for the correct application of techniques and procedures, careful inquiry at periodic intervals throughout the evaluation process can ensure sound results. As every good manager knows, monitoring and challenging technical assumptions is critically important. It is also critical for executives to monitor and ask questions about six key methodological attributes of any economic evaluation of transportation policies and investments, as follows:

- **The Base Case.** It is rarely adequate to treat the status quo as the basis of comparison for major investment proposals. Steps to redress existing problems without the need for major capital investments can liberate scarce capital resources for even more productive transportation uses. The base case should represent, as closely as possible, the most efficient and productive use of existing assets, even if expenditures are required to achieve it (Chapter 4);

- **Benefits.** All benefits should be identified. For major network improvements (in all modes), benefits associated with industry restructuring and related productivity impacts should be explored to the extent feasible (Chapter 6);

- **Costs.** All costs should be included in the economic appraisal, not just those to be financed from state and local resources (Chapter 7);

- **Discounting.** All benefits and costs must be projected over the expected service life of the *longest-lived option under review* and expressed in terms of their present-day values using the technique of discounting. Failure on either count can lead to very poor economic choices such as policies favoring annual pot-hole repair over long-term pavement reconstruction (Chapter 8);

- **Risk.** Any economic evaluation involves judgements, forecasts and assumptions, all of which are uncertain. Evaluations should expose all uncertainty and quantify its implications for decision makers to the extent feasible (Chapter 9); and

- **Incrementality.** Impact assessments of the regional employment, income and output implications of policy and investment proposals need to be expressed as differences from the "without" investment case in order to draw conclusions regarding distributional implications.

The individual chapters cited in the summaries above provide additional guidance on each respective subject.

PRIMER ON GOOD PRACTICE AND COMMON ERRORS

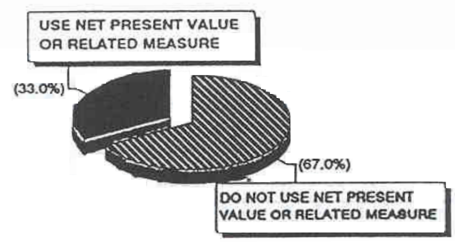
Three principles of good practice should guide the executive through the evaluation and decision making process. Common errors in all three areas punctuate the need for prudent management in the case of each one:

- **Specify economic objectives up-front.** The 1990 Survey of Current Practice indicates that information available to decision makers is often incompatible with their objectives because the choice of methodology was not linked early on to policy objectives and related decision criteria;

BOX 7

SURVEY OF CURRENT PRACTICE: 1990

Focus on Productivity and Growth-Related Objectives



Only one-third of transportation policy and investment evaluations examined in the 1990 Survey of Current Practice applied decision criteria of relevances to productivity, growth or increased living standards. The remaining two-thirds produced information on employment and income impacts and physical impacts on environmental factors. Unless growth-related tests are applied in transportation evaluations, decision makers have no way of knowing whether or not proposed policies will meet their objectives.

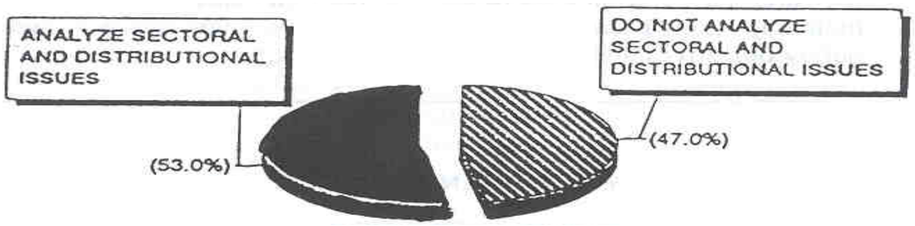
- **Emphasize Productivity and Economic Growth.** The Survey of Current Practice indicates that less than one-seventh of policy evaluations cite productivity growth as a major objective. This is in spite of the fact that, properly chosen, transportation policies are more effective in promoting productivity than they are in achieving other policy aims;

- **Choose and Apply Methodologies Correctly.** Many evaluations, according to the Survey of Current Practice, either select inappropriate methodologies or commit technical errors in their evaluation (see Boxes 7 and 8). Strong involvement in the choice of methodology and monitoring of the evaluation process represent important executive functions in the decision making process.

BOX 8

SURVEY OF CURRENT PRACTICE: 1990

Focus on Distributional Objectives



Although the majority of policy and investment evaluations focus on the distributional aspects of programs and projects, almost one-half those surveyed apply tests that do not reveal whether employment and income in the region would expand by as much or more in the absence of transportation investment. Transportation policy evaluations that reveal neither productivity nor incremental regional income impacts run the risk of decisions that promote neither net growth nor redistribution. Such decisions are wasteful by any

PRIMER ON TECHNICAL LANGUAGE AND ITS INTERPRETATION

Although methods of economic evaluation involve experts in the use of a great deal of technical jargon, its mastery is not a prerequisite for executive involvement in the evaluation process; nor is it a qualification for good decision making. Rather, executives and decision makers should be prepared to challenge technical experts to provide information in plain language. Doing so, however, requires a basic command of certain concepts and the terms used to describe them.

Two terms of jargon of emerging importance in the conduct of investment choice methodologies are "partial equilibrium" and "general equilibrium" techniques.

Partial Equilibrium Techniques

Partial equilibrium techniques refer to measures of investment performance that stop short of identifying all ramifications through the economy. Traditional benefit-cost analysis, for example, does not account for changes in production technology and logistics in private firms that can change the productivity and cost of doing business.

General Equilibrium Techniques

General equilibrium techniques attempt to trace all impacts of an investment throughout the economy. Benefit-cost analysis supplemented with industrial restructuring analysis represents a practical means of moving towards general equilibrium analysis.

PART II

FACTORS IN THE ECONOMIC EVALUATION OF ALTERNATIVE TRANSPORTATION POLICIES

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CHAPTER 4

DEFINING THE BASE CASE

Recent research and practice indicates that failure to establish the proper basis for comparison in evaluating major transportation policies and investments can result in misleading information about the economic performance of alternative courses of action.

A major corridor improvement may have a "rate of return" of 20 percent, or may promise a "net present value" of $200 million, which represents the economy's gain in relation to a world without the corridor improvement. But what would happen in the absence of the investment? Would other measures be found to improve the performance of the road system? How would traffic and the pattern of economic activity change as result? How can decision makers be assured that a major improvement program is economically worthwhile in comparison with a realistic vision of how the system would perform without it?

PRIMER ON STRATEGIC PRINCIPLES

Sound economic decisions in investment planning necessitate that major new policies, programs and investments be approved only if they can be justified after accounting for the impact of developments and actions that lead to the most efficient use of existing facilities. Rarely is it the case that "nothing happens" to improve current systems in the absence of major investment.

The "nothing happens" and "do nothing" baselines of comparison for prospective new policies assume that the transportation system and related patterns of economic activity will reflect the status quo in the absence of investment. This assumption fails on three counts.

Reflecting Realistic Demands in the Base Case Changes the Perspective on Major Investments

First, it fails to adjust demand for a program or project's services to the no-investment case. The base case for expanding highway and airport capacity, for example, should not assume that congestion would continue to expand at current rates in the absence of steps to alleviate it. Rather, the analysis needs to project how traffic would react to mounting congestion and to alternative cost and pricing incentives (see Box 9). The benefits and costs of major policy and investment options need to be expressed against a sensible baseline rather than an unrealistic projection of events in the absence of major investment.

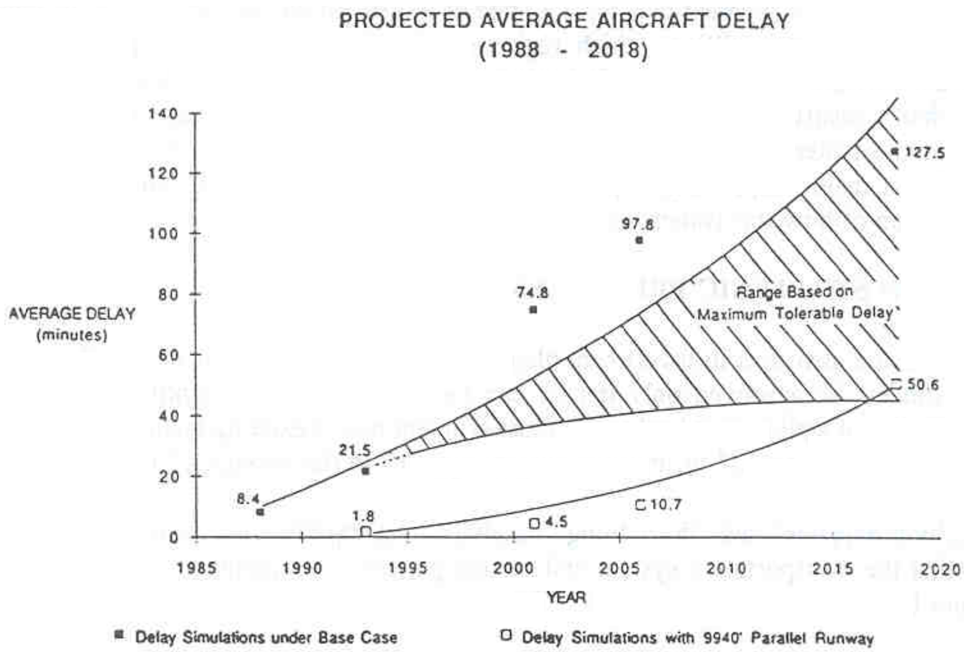
Inclusion of Productivity Improvements in the Base Case Reflects the Reality of Good Management

The second problem inherent in the status quo baseline is that it ignores steps available to state and local transportation authorities to improve the productivity of transportation systems in lieu of major expansion. In examining major policy and investment possibilities, executives are not asking whether they are economically worthwhile in a vacuum, but whether they offer net productivity gains over and above those available from less capital-intensive means of improving the transportation system.

BOX 9

CASE STUDY

Accounting for Changes in Demand in the Base Case



Failure to anticipate realistic base case scenarios can exaggerate the prospective returns from certain policies and blur the potential productivity gains from others.

Analysis of a major airfield expansion plan in the Northwest indicated that, without new runway capacity, average delays would mount to more than 120 minutes per aircraft if current trends in demand continue. Further analysis revealed, however, that some traffic would likely direct to other airports and other modes as users reached their level of maximum tolerable delay. As shown in the chart above, allowance for changing patterns of demand in the base case sharply reduced the estimated delay savings attributed to new runway capacity; by the year 2015, savings declined from 77 minutes per aircraft under the "nothing happens" baseline to zero savings under the revised base case.

The analysis also recognized that economic costs occur where users choose other airports and modes in response to delay. These costs, including inconvenience and longer travel times relative to the new runway scenario were included as *benefits* attributable to the new runway.

The case serving as a comparative baseline for major policy and investment possibilities should be a careful projection of how infrastructure systems would develop with the guidance of sound management.

Proper Scoping of the Base Case Promotes Innovative and Productive Policies

The third intrinsic problem in a base case defined by status quo conditions is that it can inhibit a broad search for innovative policies and programs of solving problems. Had the status quo served as the policy baseline for considering Ottawa, Canada's mounting congestion problem in the 1970s, for example, existing arterial roads would have been widened in order to return them to their design speeds. Instead, however, a base case was designed to maximize commuter flow with the existing system by limiting key arterials to bus-only status. The economic benefits of widening (time savings and reduced vehicle operating costs, principally) were then compared to the bus-only concept as a base case. The results indicated that the major widening option failed to outperform the base case in terms of net present value. The optimum solution turned out to be a combination of bus-only arterials and road widening, an innovative package that might well have been overlooked in the absence of a sound base case specification (see also Box 10).

PRIMER ON PROCEDURES AND TECHNIQUES

The policy option serving as the comparative baseline for major policy and investment proposals should be a careful projection of how the infrastructure system in question would develop with the guidance of sound and innovative management. Although there is no "formula" for designing the base case, at least four initiative areas have been found effective in improving the productivity of congested systems short of major capital expansion:

- **Smaller-scale Infrastructure modifications** designed to enhance traffic handling capacity of existing systems. Examples include high-speed turnoffs from runways in lieu of major airfield expansion;

- **Electronic traffic control technology** designed to obtain additional capacity from existing systems;

- **Traffic control procedures** that secure additional capacity through modified rules of traffic flow and control; and

- **Demand management** techniques, such as congestion pricing, designed to allocate scarce capacity to users who value facilities most highly (as indicated by their willingness to pay the congestion fees). Adaptations to pricing procedures have been known to include exemptions to certain groups, such as people with disabilities and trucking operations in congested urban cores, for whom the "willingness to pay" test fails to reflect the value they place on the system. The two groups in this example were exempt from a congestion pricing plan developed for central London. Executives should ensure that evaluation studies reflect a well reasoned and realistic base case package of productivity improvements such as the above; the economic performance (rate of return and net present value) of major new policies and investments -- both costs and benefits -- should be expressed as differences from the base case.

BOX 10

CASE STUDY

Choosing a Basis for Comparison - The Example of Transit Modernization

Adapted from: Congressional Budget Office;
Federal Policies for Infrastructure Management, June 1986

Both the cost structure and the regulatory pattern of current policy on transit aid follow from the perception of nearly 25 years ago that federal intervention was needed to avert widespread abandonment of transit services. Testimony presented at hearings on the 1964 Act emphasized the consequences of such abandonments, including effects on urban development and such traffic results as congestion as well as additional highway construction and vehicle purchases. Estimates were presented that, if commuter rail services were abandoned in Boston, Chicago, Cleveland, Philadelphia, and New York, the replacement highways needed would cost $31 billion. Abandoning the mass transit system in Chicago was estimated to add to the city's transport system 600,000 automobiles, 160 new expressway lanes, and extensive parking areas. Annual costs of $5 billion a year for lost time, fuel, and other costs of traffic congestion were cited.[1] The first priority of the Urban Mass Transit Administration in administering the transit capital grants program was "preservation of existing transit systems which would otherwise be abandoned" with efforts to improve and extend transit services receiving only second- or third-level attention.[2]

Rather than seek the best "without assistance" plan for improving mass transit, federal transit aid has derived from the assumption that subsidies are at all times and under all circumstances needed to retain the transit services critical to reducing urban congestion and conserving fuel. Without subsidies, according to this assumption, high fares would divert riders to automobiles, and public services needed for special groups -- including both those people without the use of private autos and those, such as the disabled, with special transit needs -- could not be provided.

The federal transit program has pursued modernization and preservation of existing systems through subsidies at the expense of other options for improving urban mobility. A look at UMTA's program, however, shows that the subsidies themselves may have caused a gap to grow between the networks of transit services available and the patterns of demand for urban travel. A result of that gap has been the marked diminution of the importance of transit services, except within finite downtown areas. Growth of major metropolitan and other urban areas during the 1950s fast outpaced the development of urban transport systems. With declining transit ridership during the decade came a general deterioration of bus services. Deliveries of new buses during the second half of the 1950s were fewer than one-third of the total ten years earlier. Failures and near failures of transit companies generated concern that even large cities could be left with no public transit. Modernization and coordinated planning were the solutions adopted, with emphasis concentrated on making up the backlog of deferred investments and little attention paid to the reconfigurations evolving in urban areas themselves.

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1 U.S. House of Representatives Banking and Currency Committee, House Report-No. 204 (to accompany H.R. 3881), *The Urban Mass Transportation Act of 1964* (April 9, 1963).

2 George W. Hilton, Federal Transit Subsidies, The Urban Mass Transportation Assistance Program, American Enterprise Institute Evaluation Studies, No. 17 (June 1974).

BOX 10 (continued)

CASE STUDY

Choosing a Basis for Comparison -- The Example of Transit Modernization

The stress on preserving existing networks obscured the importance of efficiency-oriented changes that might have made mass transit competitive in modern metropolitan areas. Bus services are most efficient when waiting times are short, routes offer (as nearly as possible) direct door-to-door service, and necessary connections are easy. Today, with focuses for trip making in modern cities split among many suburban and downtown centers -- for living, shopping, work, and entertainment -- transit services that would maintain short service intervals over wide route coverage would use small vehicles: small buses, vans, jitneys, and even taxis. Over very wide ranges of costs, the higher frequencies that bus companies could profitably offer with vehicles smaller than those most transit fleets use would reduce the costs of waiting time to riders by more than the increase in costs for vehicle operations for the more numerous services. As a result, the overall cost of commuter operations would decline.

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[3] See A.A. Walters, "Externalities in Urban Buses, "*Journal of Urban Economics*", Volume 11, January 1982.

The Base Case as an Expenditure Option

Executives should note that the base case option, unlike the "do nothing" alternative, can involve capital and operating expenditures and will certainly generate economic benefits.

These costs and benefits need to be explored in the same depth as those associated with major policy and investment initiatives and used as the base against which the expected returns on major initiatives are compared.

The Base Case as a Means of Revealing Productive Policy Initiatives

Executives and decision makers should note that the failure of major policy or investment proposals to earn a satisfactory rate of return (ie, a positive net present value) when compared with the base case means that the base case is the superior alternative.

From a decision making point of view, careful "base case planning" has been found to reveal significant policies for improving the productivity of infrastructure investments. In one evaluation examined as part of the 1990 Survey of Current Practice, a congestion fee at a crowded international airport, examined as part of the base case, was found to offer substantial gains. Analysts thus decided to test the pricing option as part of the major expansion package, and found that the combination out-performed either the base case or the major expansion alone in generating large gains in system productivity.

It should also be noted that more than one base case option can be developed and used in the evaluation process. In the airport expansion study discussed above, for example, the base case involved steps from all four of the initiative areas with two variants, each based upon an alternative approach to peak period surcharges (category four). The variants proved to be of critical value in the final decision making process since one of major investment alternatives (a stub runway) proved superior to one of the base case options but not to the other. The stub runway was thus eliminated from further consideration since a feasible and far less costly demand management option would out-perform the stub runway from an economic point of view.

PRIMER ON GOOD PRACTICE AND COMMON ERRORS

Good practice requires both sound and innovative base case design; the base case is not a trivial benchmark against which the economic performance of major policies and investment proposals can be compared. Rather, the base case needs to be viewed as a serious option, or set of options, in its own right. The base case can expose important productivity initiatives; indeed, executives and decision makers find that their personal involvement in base case design can promote a creative process and thus serve as a catalyst for imaginative and innovative planning.

As shown in Box 11, the 1990 Survey of Current Practice indicates that the most common error in this area is reliance upon either a "nothing happens" or a "do nothing" scenario as the baseline for comparing the economic implications of major policies and investments.

PRIMER ON TECHNICAL LANGUAGE AND ITS INTERPRETATION

Executives and decision makers alike should be familiar with the "base case" as a concept. All parties, executives, decision makers and practioners alike, need to share the common view of the base case as more than a technical step in the evaluation process; as well, it should be viewed as part of the creative process of seeking productive improvements to the transportation system.

Base Case Components

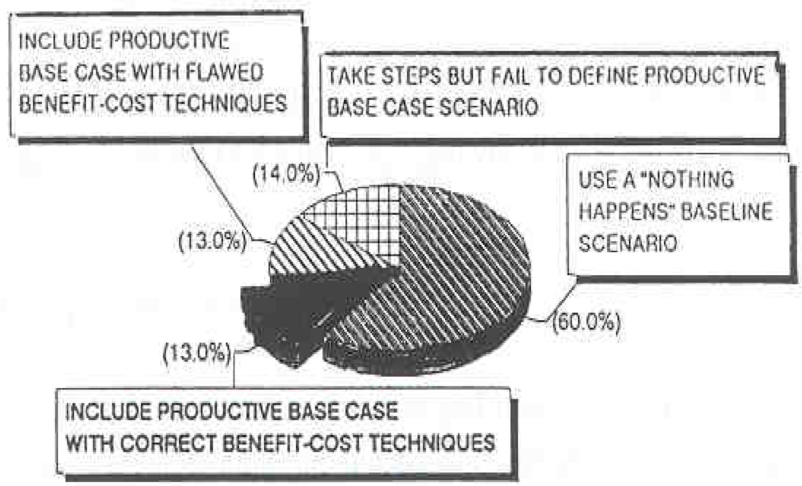
The term "base case components" refers to valid steps for consideration in designing base case options. These include:

- Small-to-medium scale infrastructure modifications;
- Automation and technological innovation to ease congestion or enhance predictability of ourney times;
- Changes in traffic management procedures;
- Congestion pricing or surcharges; and
- Privatization to test the economic viability of proposed investments.

BOX 11

SURVEY OF CURRENT PRACTICE: 1990

Specification of the Base Case



The Survey of Current Practice found that no more than 26 percent of the policy evaluations examined developed an efficient and productive Base Case as a Basis for assessing major improvements. This practice sharply limits the search for productivity gains from transportation policies.

CHAPTER 5

IDENTIFYING POLICY AND INVESTMENT ALTERNATIVES

The creative process involved in the development of base case options carries over into the identification of major policy and investment alternatives. From the viewpoint of decision makers' economic objectives, the overriding challenge is the search for transportation policies and investments that lead to increased productivity, growth and living standards.

PRIMER ON STRATEGIC PRINCIPLES

The search for productive transportation policies and investments is a creative process and there can be no fixed "road map" to guide the agenda. There are, however, five key principles that together sum to a "way of thinking" about transportation policy that can trigger and sustain innovation and creativity in the search process.[34] These principles translate directly into useful questions that executives and decision makers can use in auditing and scrutinizing the planning process.

Search Widely for Solutions: The Re-emerging Importance of Network Expansion

While limited planning and administrative resources will condition the search for new or innovative planning approaches, other kinds of limits can work against the search for productive investments. The greatest barrier perhaps is one of attitude. Consider the following quotation:

> Most (infrastructure) programs are managed not to support and promote broad policy goals but instead to provide capital for predetermined types of projects. Though these projects were generally chosen to promote broader goals, the criteria and standards for completing the projects themselves, rather than their effects on community well-being, have tended to become the focus of management. For example, careful attention is paid to engineering standards for roads, while little is paid to the effects of road improvements on transportation efficiency (and productivity).[35]

Attention to productivity demands that, in addition to sufficiency ratings and other engineering and design-based approaches to finding investment alternatives, infrastructure managers need to shape investments around opportunities to reduced vehicle operating costs, diminish congestion and delay and release potential in business and industry to achieve structural gains in productivity. As discussed next, recent research emphasizes the importance of improved network reliability and predictability in journey times in promoting such gains in productivity.

Reliability, Predictability and the Growing Importance of Large-Scale Network Improvements. One of the most important findings in newly surfacing research is the

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[34] These principles are drawn from a series of studies on infrastructure management conducted by the Congressional Budget Office from 1983 to 1989. See in particular, **Federal Policies for Infrastructure Management**, June 1986 and New Directions for the **Nations Public Works**, September 1988.

[35] Congressional Budget Office, **Federal Policies for Infrastructure Management,** June 1986.

importance of *reliability* and *predictability of journey times* in association with transportation improvements, improvements that are often available only through large-scale network improvements. It now appears that improvements that create more predictable journey times are far more significant in producing productivity gains than improvements which yield reductions in average journey times alone. This is because vehicles -- trucks in particular -- are often unable to take full advantage of design speed improvements due to statutory and self-imposed driving restrictions. Cost savings are more likely to arise from actions taken by firms to maintain total driving times but reduce the number of ancillary transportation facilities such as depots, terminals and inventories -- steps made possible by greater system reliability and more predictable journey times.

Major private sector productivity gains from transportation improvements will thus stem from reduced overhead and warehousing as well as (or even in lieu of) diminished fuel and vehicle user costs as traditionally assumed. This of course changes the nature of transportation design improvements that executives need to consider in establishing transportation policies and investment programs.

The findings reported above stem from studies in business and industry logistics. It is now understood, for example, that truck drivers face statutory limits on duty times which limit the extent to which they can fully capture potential time savings from roadway improvements. They also face danger to life and limb (both their own and that of others on the road) in the use of "opportunistic driving" to capture the potential benefits of higher speeds from reduced congestion. Their employers recognize this in imposing strict rules of conduct.

The above means that many firms are more likely to capture the full benefits of highway improvements only if the improved predictability of journey times (rather than reduced *average* journey time) is significant enough to permit a restructuring of distribution logistics. Restructuring could involve, for example, a reduction in the number of a furniture manufacturer's distribution depots used to service a given territory of retail branches. Cutting out depots allows the firm to reap productivity gains in the form of lower inventory, lower overhead and an economy of scale (more output per dollar of overhead) while maintaining the same total driving time and driving speed. The firm will only accede to a structural reduction in inventory, however, if it can be assured that the corresponding increase in deliveries will be predictable and on-time. The adoption of just-in-time inventory and delivery technology is especially sensitive to predictability.

Reductions in congestion along single roadway segments offer better *average* journey times but do not necessarily offer proportionately greater predictability in journey times (since variation around the average depends upon activity in other segments of the network as well). Logistics analysis suggests that only large-scale network improvements can offer both faster *and* more predictable journey times and thus trigger the full scope of productivity gains available to business and industry as a result of transportation improvements.[36]

Maintaining the Existing System Versus Network Expansion: Is the Highway and Airport System Really Complete? Significant improvements in the predictability of journey times can

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[36] See, D.A. Quarmby, **Developments in the Retail Market and their Effects on Freight Distribution**, Journal of Transport Economics and Policy, Vol. XXIII no. 1, January 1989.

often be achieved only through network improvements (whether in highways or airports and airways). The newly emerging significance of large-scale network improvements as a means of enabling major business and industrial productivity gains brings into question the common belief that the limited access highway system and the airport and airway system are largely "complete." Transportation officials need to search continuously for innovative means of improving reliability and predictability of journey times through network additions, network design improvements, and automated navigational systems. These may offer substantial promise of major returns for the economy when their full implications for productivity are explored.

Recognize the Interdependencies Among Investment Options

The economic benefits and the costs of one investment opportunity may be sharply affected by those generated by another; such interdependencies, even where they exist in different states, need to be considered in shaping investment plan. Failure to consider interdependencies can lead to both heavy over and underinvestment. The 1990 Survey of Current Practice revealed, for example, a number of projects in which the traffic forecasts failed to account for the development of competitive facility developments elsewhere. The case study of a container port expansion project, for example, found that when allowance was made for improvements at a similar facility 50 miles away, the net present value of the proposal turned from positive to negative.

Examples have also been found of situations in which failure to account for the impacts of *complementary* facilities leads to an underestimate of the net economic benefits of transportation improvements. Highway improvements near expanding airports, for example, create opportunities for a more broadly dispersed locus of businesses in the region to take more productive advantage of air travel for business purposes, a benefit that exists only because of the combined impact of improvements to both facilities. Complementary impacts create investment opportunities whose benefits can be substantially greater than the sum of their parts but they are rarely assessed in practice.

Focus on the Objectives to be Served Rather Than on Finding Ways to Improve Or Expand Existing Facilities

Limiting policy choices to expansions or improvements of existing facilities has been found to obscure the potential productivity gains that may be available from better management (reorganized bus schedules as a possible alternative to increased fleet size, for example) or from direct gains in labor productivity (such as improved training programs). Limiting options to those which improve physical facilities risks overlooking large potential improvements from changes in operating practices that increase the quality of services provided.

At the same time, assuming that a street, highway or aviation network is "complete", and focusing only upon bottlenecks, can camouflage the potential productivity gains from network improvements, especially for the productivity of private firms.

At the State Level, Avoid Limiting Options to Those Under the Control of a Particular Transportation Agency or Jurisdiction

Limiting options to those of a given authority runs the risk that the agency's aims, rather than broad state objectives, will be the object of decisions. Ways to improve commuter services, for example, include new and improved roads, new subway systems, dedicated lanes for high occupancy vehicles, and changes in downtown parking regulations and prices. Restricting choices just to those for increasing mass transit services, for example, creates the risk that the most productive or the least costly way of improving an urban transport network as whole will be overlooked, or that transit services will be improved with little reduction in overall commuting costs. Although it will not always appear practical to do so, questions of authority and jurisdiction would best be left until after the most productive plan of action has been determined.

Consider Timing as a Strategic Issue

As shown earlier in the Primer, the issue of *when* to expand is as important to productivity as *whether* to expand. Considering the effects of infrastructure options over the useful lives of facilities is critical in the search for productive policies and investments. Projects can appear to offer strong returns over their useful lives, but be premature from the viewpoint of current problems. Different actions can be effective over different time spans, and the most efficient long-term solutions may include a mix of major capital investments, productive "base case" improvements and changes in operating rules and managerial practices. Policy alternatives should thus be viewed as packages of variously timed and structured initiatives.

Develop Priorities by Comparing Broad Policy Alternatives in Terms of Their Contribution to Productivity

Contrary to the popular belief that economic analysis can only be conducted for specific projects, very broad program and policy options can, in fact, be compared in terms of their return on investment and contribution to productivity. As shown in Box 12, broad investment strategies can be compared in terms of their rate of return and thus their contribution to productivity. Such comparisons can then be used to help identify policies with the greatest likelihood of stimulating productivity growth and policy-level priorities can be established accordingly.

PRIMER ON PROCEDURES AND TECHNIQUES

From the viewpoint of the executive and the decision maker, the day-to-day application of engineering and economic procedures and techniques in the development of alternative policy and investment choices must rest at the technical level. As discussed below, however, good practice dictates periodic involvement of both executives **and** decision makers in the process of establishing the range and content of policy options.

PRIMER ON GOOD PRACTICE AND COMMON ERRORS

Any transportation policy or investment program will have many stakeholders, including the planners; the decision makers; elected officials not directly involved in the decision process; users of the transportation system in question; businesses affected by changes in the transportation system; and those for whom changes in the system may have deleterious environmental impacts.

Recent breakthroughs have occurred in group dynamics and public involvement in public decision analysis. The application of these techniques to transportation planning has demonstrated that involving stakeholders in the process of identifying alternative directions *and* in the process analyzing their broad economic implications can substantially improve the likelihood of consensus

BOX 12

CASE STUDY

Setting Broad Priorities on the Basis of Productivity Criteria

Investment Strategy	Expected Real Rate of Return on Investment (National averages)
4R Projects to Maintain Current Highway Conditions (Average Present Serviceability Ration of 3.1)a	30 percent to 40 percent
New Construction, Urban Areas	10 percent to 20 percent
4R Projects to Upgrade Sections Not Meeting Minimum Service or Safety Standards	3 percent to 7 percent
Projected 1993 Federal, State, and Private 10-Year Borrowing Rate (Social Opportunity Cost of Capital)	*3 percent to 4 percent*
New Construction, Rural Areas	Low[b]
4R Projects to Fix All Deficiencies Above Minimum Service and Safety Standards	Negative

SOURCE: Congressional Budget Office, based on data from the Federal Highway Administration.

NOTE: 4R projects are those involving restoration, resurfacing, rehabilitation, or reconstruction.

a. Present serviceability ratings score highway conditions on a scale from 0 (very bad) to 5 (excellent). A rating of 3.1 puts the Federal Aid System in good to very good condition.

b. Economic returns may be higher for replacement of substandard bridges on the national truck network.

In 1988, the U.S. Congress commissioned a review to examine the broad productivity implications of alternative highway investment strategies. Using rates of return drawn from Benefit-Cost Analysis, the analysis revealed that 4R projects to maintain current highway conditions tend to produce the highest productivity impacts, with returns that 10 times higher than estimated social opportunity cost of capital. New construction in urban areas is found, in general, to be next in terms of productivity potential. New construction in rural areas is found to perform only marginally in relation to the social opportunity cost of capital. These projects are found to yield positive rates of return, however, and may be justified on a case by case basis to serve distributional objectives.

and action on productive investments. This has been demonstrated in highly controversial investment areas -- such as those involving noise and neighborhood dislocation -- investments that might otherwise be seriously delayed. Earlier chapters of the Primer have documented the serious economic losses entailed in the delay of productive transportation investments. Chapter 9 is devoted to a description of new techniques of consensus building in public investment.

PRIMER ON TECHNICAL LANGUAGE AND ITS INTERPRETATION

All parties -- executives, decision makers, practioners and stakeholders -- need to share in the process of developing policy alternatives. This requires a common language and for the most part there is no reason why plain English should not suffice. Certain terms, however, take on special meaning in the context of designing alternatives.

Predictability of Journey Times

Steps to reduce congestion can increase average speeds proportionately less than the corresponding improvements in improved predictability of journey times (depending upon characteristics of the overall network that remain congested). Since distribution operations hinge more on predictable scheduling than average speed, this distinction is important.

Project Interdependencies

Some investment opportunities may have important linkages with other facilities and services, often within the same network. Failure to identify interdependencies can lead to missed opportunities for innovative solutions or the over or underestimation of project costs and benefits.

CHAPTER 6

IDENTIFYING THE BENEFITS OF TRANSPORTATION POLICIES

Although misconceptions about the economic effects of transportation policies and investments endure, the characteristics of their direct economic benefits are well understood and documented.[37] Emerging research indicates, however, that the traditional framework used to identify these benefits is itself limiting and that certain benefits associated with major network-related policies and investments will be overlooked under the traditional approach.

PRIMER ON STRATEGIC PRINCIPLES

The executive and decision maker can usefully think of the productivity, growth and welfare-related benefits of transportation policies and infrastructure in two categories, as follows:

- Benefits associated with the traditional economic framework; and
- Benefits associated with industry restructuring.

Benefits and Costs Associated with the Traditional Framework

Analysts agree that the traditional framework for defining the economic benefits of transportation policies, though limited in certain respects (see section on industry restructuring below), remains valid as a basis for defining transportation. The fundamental underlying principle is that only real savings in economic resources can be counted as benefits; the redistribution of economic activity from one region to another might affect social objectives but will not in any way contribute to net gains in economic growth.

Based upon this principle, benefits from transportation policies and investments fall into two principal categories:

- Savings in transportation users' costs; and
- Productivity gains in the management, operation and maintenance of the transportation system.

Savings in Transportation Users' Costs. Real resource savings from most transportation improvement projects arise in the form of savings in vehicle operating costs, reductions in travel time and associated productivity gains and savings in accident costs. Savings in these three

[37] See, for example, American Association of State Highway Officials, **A Manual on User Benefit Analysis of Highway and Bus-Transit Improvements,** 1977; James H. Batchelder, **Application of the Highway Investment Analysis Package,** Transportation Research Board Record, 1987.

categories are especially large in the case of policies to reduce highly congested systems. Newly emerging research and project evaluations indicate that the economic value of time savings associated with steps to reduce congestion is substantially greater than previously thought. In the case of highway repair and reconstruction of congested systems, rates of return vary from 30 percent to 40 percent; new highway construction in congested areas generates returns in the 10 percent to 20 percent range (see Box 12). The addition of new capacity at the 20 most congested airports yields average rates of return in excess of 100 percent according to evaluations reviewed in the Survey of Current Practice.

A range of well developed technical procedures are available to practioners to aid in the forecasting and estimation of these benefits. From the viewpoint of executives and decision makers, however, the forecasting process involves important judgements and assumptions that are technically uncertain and require challenge and review. Paramount here are the assumed monetary values of time savings; the assumed monetary values of life and limb in the valuation of accident savings; and the assumed relationships between changes in the design-attributes of infrastructure (such as the addition of lane-miles to a stretch of highway) and corresponding change in vehicle operating costs. Each of these three factors is subject to uncertainty (see Primer on Techniques and Procedures below) and executives should ensure that evaluations test the sensitivity of study results to variation in these underlying assumptions (see Chapter 9).

Productivity Gains in the Operation and Maintenance of the Transportation System. Transportation improvements that involve automation and other labor saving initiatives create productivity-related savings in the operation and maintenance of the infrastructure itself. Plans to automate the nation's air traffic control system are expected to reduce the number of air traffic controllers by as much as 40 percent while accommodating an increased workload in terms of flights handled. As shown in Box 13, the associated productivity benefits are estimated to exceed the sum of all other categories of economic benefit attributed to the project.

Research indicates that while the potential for actually achieving large economic gains from automation is real enough, substantial economic risk attaches to the timing of benefits. Benefits from the air traffic control plan in question are now substantially behind, due largely to longer-the-expected research and development and "shake-down" requirements. As discussed in Chapter 9, executives and decision makers need to be aware of such risks. For major proposals, executives and decision makers should expect quantitative information regarding the economic costs of possible slippages. In particular, risk analysis of first-year benefit ratios should reveal the likelihood that major automation projects, such as "smart-car" technologies, would fail to earn adequate rates of return in the early years of operation.

Benefits Associated with Industry Restructuring and Network Improvements

It is conventionally assumed that the value of user and system benefits incorporate the total value of productivity and output gains that occur throughout the economy as a result of investment. A highway project, for example, will improve travel times for workers and reduce operating costs for trucking. To the extent that such benefits are passed along to industry, they permit greater output for a given call on labor and transportation resources. Depending upon the strength of competitive market forces in the industries in question, consumers will gain from lower prices.

While the kind of interactions outlined above will capture economy-wide impacts if there is no change in the production processes and technologies of firms, there may be conditions under which further impacts would occur and the question has recently been raised whether the conventional yardstick of "user-benefit" captures such effects. Such impacts include fundamental technological changes in industry that transportation infrastructure improvements permit and which bring about structurally improved productivity.

As explained in analytic detail in the Technical Report, it is now known that the conventional framework for measuring benefits does not capture productivity impacts associated with structural change in industry. Although the research community's understanding of such impacts and how to measure them is in its infancy,[38] it is known that major policies and programs that improve the *reliability* of the transportation system, particularly through network improvements, can lead firms to reorganize their logistics and distribution networks as a result. Reduced congestion *throughout a network* improves the reliability of delivery schedules so that smaller and more frequent deliveries are made; this in-turn facilitates reduced inventory, handling and packaging costs. As shown in Box 14, firms may also eliminate distribution centers, clustering fewer depots around key points in the improved transportation network. The Technical Report provides a newly developed technique, called Industrial Restructuring Analysis, to help measure and quantify these impacts.

Industry Restructuring, Productivity and the Policy Making Process. The case study reported in Box 14 indicates that accounting for the productivity gains associated with restructuring can sharply increase the estimated benefits associated with major improvement programs. Methods are now surfacing to quantify such impacts. The Industrial Restructuring Analysis process includes a data collection system together with a companion computer program to assist in the rather complex computations. Both are available with the Technical Report.

As shown in Annex A to this Primer (with elaboration in the Technical Report) industrial restructuring analysis requires transportation officials to liaise and consult with private industry as a means of gauging how major policies to improve the *reliability* of the transportation network might yield industry-related productivity gains over and above those measured in the conventional framework. Logistics managers of private firms are trained to recognize opportunities to improve their productivity by adjusting to more reliable infrastructure and a dialogue between transportation and industry managers is becoming a fundamentally necessary part of the policy making process.

Full application of industrial restructuring analysis requires the use of newly developed economic analysis procedures; the computer program available with the Technical Report will perform the necessary computations. However, even if states and localities conduct the industry consultation phase alone, without attempting to quantify the results in the form of formal benefit estimates, the exercise should yield important insight for the development of indicative spending targets and policy priorities with regard to the scale, type and location of major network improvements.

[38] Much of the development, thus far, was conducted during the research phase in developing the Primer.

BOX 13

CASE STUDY
Accounting for the Full Range of Benefits
Projected Federal and Direct User Benefits
(In millions of dollars)

Fiscal Year	FAA Net Operating Cost Savings due to Productivity Gains	Fuel Cost Savings			Safety Benefits	Projected Microwave Landing System (In millions of dollars)					
		Air Carriers	General Aviation	Total		Reduced Disruptions		Reduced Outages	Ground/Air Savings	Path Length Reductions (Time Savings)	Total
1982	90	0	0	0	0	0	0	0	0	0	
1983	280	0	0	0	0	0	0	0	0	0	
1984	470	0	0	0	0	0	0	0	0	0	
1985	660	0	0	0	0	0	0	0	0	0	
1986	780	150	50	200	4.8	34.8	8.5	26.0	19.5	93.6	
	•	•	•	•	•	•	•	•	•	•	
	•	•	•	•	•	•	•	•	•	•	
	•	•	•	•	•	•	•	•	•	•	
2004	2,640	910	430	1,340	17.4	183.1	16.5	157.4	78.4	452.8	
2005	2,750	920	440	1,360	17.7	190.1	17.2	164.5	81.1	470.6	
Total in 1982 dollars											
1982-2000		24,295	6,850	2,970	9.820	193.4	1,638.6	161.4	1,239.3	738.7	3,971.4
1982-2005		37,085	11,290	5,070	16,360	279.1	2,521.3	240.5	1,993.8	1,117.8	6,152.5
Total Present Value (At 10 percent discount rate)											
1982-2000		8,902.0	2,001.9	843.1	2,845.0	63.1	536.5	58.4	398.2	247.1	1,303.3
1982-2005		10,638.6	2,622.0	1,127.2	3,749.2	76.7	655.4	69.1	500.3	298.3	1,599.8

SOURCE: CBO from FAA data.

A federal evaluation of plans to modernize the air traffic control system identified eight categories of productivity and user benefits. No attempts were made to identify productivity benefits from industrial restructuring.

PRIMER ON PROCEDURES AND TECHNIQUES

A range of well developed technical procedures are available to practioners to aid in the forecasting and estimation of economic benefits. From the viewpoint of executives and decision makers, however, the results of the evaluation process hinges foremost upon important judgements and assumptions; these are technically uncertain and require executive challenge and review. This section provides the executive and the decision maker with the background needed to execute the challenge and review process.

Key assumptions in the economic evaluation process are (i) the assumed monetary value of time savings; (ii) the assumed monetary value of life and limb in the valuation of accident savings; and (iii) the assumed relationships between changes in the design-attributes of infrastructure (such as the addition of lane-miles to a stretch of highway or a new runway) and the corresponding change in vehicle operating costs.

Executives will note from the discussion that follows that much remains to be resolved in developing a single standard of quantification. This does not diminish the value of economic analysis, however; rather, it punctuates the importance of (i) risk and sensitivity analysis of all key findings -- see Chapter 9 -- and (ii) strong executive involvement and sensitive judgement in the use of analytic information.

The Economic Value of Time Savings

Time is an economic resource with real if uncertain value. In the case of policies that affect passenger transportation, savings do not arise in monetary form but in saved time itself, the economic value of which depends largely upon how the time would be used in an alternative use.

The Value of Working Time. When passengers travel in working time, time *savings* have economic value to the extent additional productive work can be performed. Employers recognize this routinely in permitting travel by air as opposed to less expensive, slower modes and in providing company cars for short journeys. Travellers themselves demonstrate the value of time savings when they pay more for faster transportation (such as toll road over a free secondary highway).

A key test in assessing the true economic value of congestion-reducing policies is the amount travellers (or their employers) are willing to pay in order to save time. To obtain practical answers to the willingness-to-pay question, one can ask, "what would business travellers do with the time saved?" Would they use it for productive work and would their labor be recompensed and thus an economic factor? If the answer is "yes" then travellers' average hourly wage rate (the market economy's valuation of an hour worked) represents a reasonable approximation to the economic value of time saved (ie, the wage rate multiplied by the amount of time saved).

The Question of Small Time Savings. Researchers have explored a number questions that might suggest the need for a correction to the wage rate as an index of the value of time savings. Some conclude that the wage rate overstates the value of time savings. The most common reason given for this conclusion revolves around the matter of small time savings -- can a reduction in travel time of only a few minutes (usually defined somewhere between five and 15 minutes) be put to productive use (or, more precisely, can small time savings yield *marginal* productivity gains of equivalent value to the *average* productivity levels reflected in wage rates). Some analysts argue that small time savings during working time are rarely used for work purposes and are perceived instead as leisure time (time to catch one's breath or just relax) and should thus be valued accordingly. Under this reasoning, small time savings would be valued at a lesser amount than larger time savings.

Those who oppose a correction for small time savings point out that people regularly pay money in order to save small amounts of time (taking a cab instead of a bus on a short journey, for example). Recent research conducted for the Federal Aviation Administration, and independently at Oxford University, argue against the devaluation of small time savings, reasoning that if small savings in working time were not productive, the many small improvements introduced regularly into transportation systems (better sequencing of traffic lights, one way systems, more efficient queuing systems at airports, and so on) would leave workers with little pockets of "time to kill" over the course of the day. Since research has been unable to detect such a phenomenon, it is argued that workers, on the whole, transfer even small time savings into productive use.

Is Travel Time Entirely Wasted? Since hourly wage rates represent the labor market's valuation of an hour worked, the use of wage rates in valuing time *savings* presumes that time spent in travel is entirely wasted. A common argument for valuing savings in working time at less than the wage rate points out that some people engage in productive work while in travel (especially on longer journeys aboard aircraft) and that delays are not entirely wasted. Indeed, many workers build time in transit into their work schedules for writing, dictating, "quality-time" for thinking and so on. While the truth in this observation cannot be denied, some economists argue that it is anecdotal rather than systematic and that productivity levels in travel are structurally and substantially lower than they are in a normal work environment.

On the other hand, some researchers contend that the wage rate understates the value of savings in working time because it ignores improvements in labor and capital productivity that stem from reduced travel times. For example, when a worker is delayed because of airport congestion, his staff and office computer might be idle, or less productive than would otherwise be the case. Using this line of reasoning, some researchers supplement the wage rate with an "overhead" premium in estimating the value of passenger time savings.

The Question of Journey Time Predictability. From logistics research, it is known that a key feature of the road network, one which governs the definition and scheduling of work on a warehouse or depot's territory, is the predictability of journey times. A recent British study[39] concludes that current practice in the valuation of time savings is deficient in failing to take account of unreliability in terms of expected arrival times. The study finds that users value time savings in congested conditions some 40 percent more highly, both in highway and transit use.

The Value of Non-Working Time. Time saved in non-work related travel is thought to occasion less value than time savings gained by workers since productive activities contribute more to economic development than consumption activities. Empirical evidence also indicates a lower value; note for example peoples' greater willingness to take slower and less costly modes or routes in non-working time.

[39] MVA Consultancy and Institute for Transport Studies, Leeds University, and Transport Studies Unit, Oxford, The Value of Travel Time Savings, Policy Journals, Oxford, 1987.

Even so, leisure time can be assumed to occasion some economic value, as evidenced by the fact that people are willing to pay to achieve travel time savings in non-work time; the valuation problem is one of empirically observing peoples' actual willingness to pay for savings in non-work travel time as a basis for economic evaluation. (Note that, logically, an hour spent travelling during one's leisure time does not actually deprive one of an hour's worth of leisure - - it merely involves using leisure time in one way versus another. Thus, what the analyst actually needs to measure is the difference in value between an hour's leisure spent in travel and an hour's leisure spent in an alternative use.)

Standard Values of Time. There is no single, correct set of assumptions to apply in the valuation of time savings. Standard values will probably never emerge. The available theoretical and applied research indicates that, on balance, the evidence weighs in favor of the wage rate as a "central case" in valuing working time savings, with substantial upward adjustments in congested conditions.

In the case of non-work travel, the body of empirical research suggests an amount equivalent to some 40 or 50 percent of the wage rate as a central case. Of course, these values are not definitive and the importance of conducting sensitivity and risk analysis in the conduct of project evaluations cannot be overstated.

The Economic Value of Transport Safety

All states and localities maintain a long-standing policy that gives safety absolute priority above all other objectives in the provision of transportation facilities and services. A transportation system must be safe or it will not be made available to the public.

Like any other publicly provided service, safety requires resources and resources are always less plentiful than the number of uses society can conceive for them. This creates a dilemma in planning for public expenditures since the number of good ideas for making safe transportation systems even safer inevitably exceeds the dollars available to put all the ideas in place.

Moreover, state and local policies also reflect society's transportation objectives in areas other than safety. If society valued improved safety alone, other objectives such as speed, comfort and convenience could be ignored and all state and local resources directed at the implementation of ideas to make safe systems safer (including regulatory actions governing speeds, air bags and so on). To be sure, the public often makes strong demands for more safety and accepts that the additional safety is worth the costs. At the same time, however, people can be observed to accept some risk to their safety in order to achieve other goals, such as driving at speed in order to reach a destination more quickly; or using a mode of travel they perceive to be less safe in order to save time and improve their earnings.

Transportation authorities thus recognize that making safe systems safer competes with other aspects of transportation productivity and with all other possible uses of resources. A socially acceptable allocation of resources among these uses requires that the value of transport safety improvements somehow be compared with the value of using the resources in other ways.

In economic evaluation, a useful approach, if feasible, is to compare improved safety in the same units as other benefits -- namely money -- in order to facilitate and simplify the desired comparisons. A large body of literature exists on the question assigning value to life and limb; some authorities test the implications of such values in order to compare projects while others prefer a qualitative approach.

The Use of Threshold Analysis. One of the more popular methods is known as threshold analysis. The analyst first computes net present value without taking safety benefits into account. If the resulting net present value is negative, the analyst can calculate the value of life and limb that, when applied to the projected reduction in accidents, would bring the project into a position of economic viability. Under this approach, decision makers can benefit from the intuitive understanding that a threshold analysis can provide.

The Impact of Infrastructure on Vehicle Operating Costs

Improved highways, runways, airways and seaways lead to reduced operating costs for vehicles, aircraft and vessels. Statistical estimates have been developed over the years that provide guidance but these are subject to uncertainty in each case.[40] Executives should always challenge and review the use of such relationships and report the results of sensitivity analyses to decision makers in cases where rate of return or net present value estimates turn on the results.

PRIMER ON GOOD PRACTICE AND COMMON ERRORS

As emphasized throughout this section of the Primer, the essence of good practice is constructive challenge and review of both technical procedure and assumptions. There are, however, three key areas of potential weakness in which executives should be especially vigilant, (i) the identification of all categories of benefit; (ii) the treatment of employment impacts; and (iii) the approach to land-related benefits.

Identifying Benefits

As shown earlier, a wide range of valid economic benefits need to be counted in the economic evaluation of transportation policies and investments. As shown in Box 15, only one-fifth of the evaluations examined in the Survey of Current Practice count all significant areas, thus leading many studies to understate the actual value of transportation investment.

Employment Impacts

The key point here is that, from an economic point of view, direct employment impacts represent a *cost*, not a benefit, of transportation policies and investments. The capital and operating expenses associated with a highway improvement or a transit investment include the cost of labor in the construction and on-going maintenance process. This is as it should be since labor is a scarce resource and only those investments with benefits high enough to consume the resource

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[40] In the case of highway design, the National Cooperative Highway Research Program is establishing a major research program to substantially improve the state of knowledge in this area.

BOX 14

CASE STUDY
Accounting for Industrial Productivity Benefits Associated with Major Network Improvements

Sainsbury's, Britains largest supermarket chain, considered the impact of a road network improvement on food distribution. The road improvements are seen to have two impacts. One is to reduce the driving time required for trips. The second, as a result of the faster driving time, is to permit the firm to make a major structural change in logistics, namely to reduce the number of its depots from 6 to 5. The closure of depots requires an increase in the number of miles travelled of 9.5%, but the additional cost is outweighed by the savings from closing a depot. Savings in closing the depot come from reduced inventory holdings and economies of scale in handling increased volumes of goods with one less depot.

The firm looked at the measurement of benefits in two ways. Case A, counts only the savings in driving time and associated costs, assuming that the structure of the firm's operations remains the same. Case B, considers the additional impact from the reduction in the number of depots.

Savings from Improvements in Road Network

	Per case handled
	British Pence (p)
Case A	
- Transport savings without restructuring	1.3
Case B	
- With Restructuring	
Marginal volume benefit	1.6
Stock saving	0.5
	2.1
Less extra transport cost	0.5
Total	1.6
- *Extra benefit* over transport savings	0.3 over 1.3p = 23%

The analysis indicates that true benefits to the firm, including the benefits of restructuring, are 23 percent higher than those captured by conventional Benefit-Cost practice which would measure only the direct benefits from faster travel time.

Formal theoretical extensions of the traditional Benefit-Cost framework developed for the Primer confirm the validity of the Sainsbury's analysis, (see Technical Report). Other tests conducted in the Technical Report indicate that failure to account for productivity impacts can understate the true economic of major improvements by more than 100 percent.

should be accepted -- economic evaluation measures investment returns accordingly. Thus to include employment as a benefit would simply nullify the very purpose of the analysis.

Situations in which it is appropriate to count employment impacts as benefits do arise, but they are very rare and difficult to justify. Only where it can be shown that a project would employ long-term, structurally unemployed workers *and* that the same level of employment could not be generated through use of the funds in another way.

Approach to Land

Since the value of user benefits is reflected in any increase in land values that result from a project, it is usually wrong to include the increased value as a benefit. If, however, land is expected to increase in value relative to other prices, its value in its next best use (ie, its "opportunity cost") needs to be taken into account and only the incremental increase included as a benefit.

PRIMER ON TECHNICAL LANGUAGE AND ITS INTERPRETATION

Executives and decision makers alike should expect practioners to present their results in everyday language while sustaining high technical standards. Doing so is also imperative if the public at-large is to become progressively more involved in the policy and decision making process (as discussed further in Chapter 9). As in other aspects of the process, however, certain key terms occasion special meaning.

Industrial Restructuring Analysis

A new addition to the traditional battery of benefit-cost analysis techniques, industrial restructuring analysis assesses the extent to which business and industry will adopt more productive production and distribution technologies and logistics as a result of major changes in transportation networks.

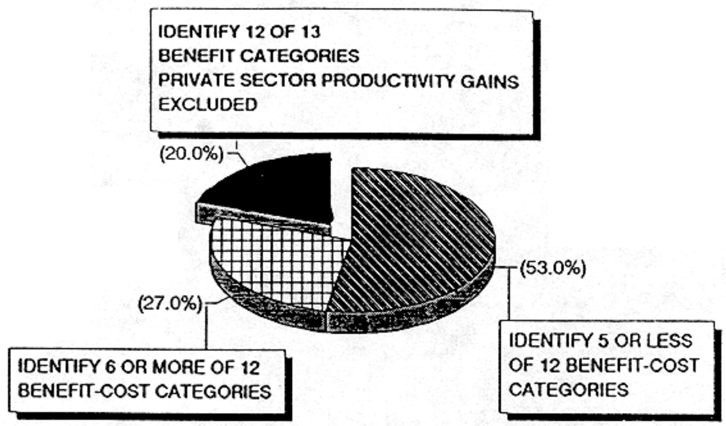
Willingness-to-Pay

The willingness of transportation users, business and industry to pay for time savings, safety gains or production efficiencies represent a key measure of the economic value placed upon these benefits. Valuations based upon willingness-to-pay, whether drawn from market prices or survey-based statistical evidence represent a valid basis for assessing economic benefits.

BOX 15

SURVEY OF CURRENT PRACTICE: 1990

Identification of Benefits



The Survey of Current Practice suggests that 80 percent of the policy evaluations conducted identify less than one-half of benefit categories attributable to their investment proposals. This practice leads to an under-statement of the value of transportation and to long delays in the approval and implementation of policies and investments.

CHAPTER 7

IDENTIFYING THE ECONOMIC COSTS OF TRANSPORTATION POLICIES

When capital, labor and environmental resources are used up in a transportation system, people sacrifice the use of these resources for other purposes. It is the value of these forgone opportunities (called, "incremental opportunity costs" in the jargon) that need to be considered in the conduct of an economic evaluation.

PRIMER ON STRATEGIC PRINCIPLES

Five principle categories of economic cost can be identified for most transportation policies and programs:

- Capital expenses;
- Disruption costs;
- Annual incremental operating and maintenance expenses;
- User costs; and
- Environmental costs.

All costs need to be projected annually, in dollars of constant purchasing power, over a time-period corresponding to the longest-lived facility under consideration. This ensures that short-term and long-term solutions -- highway crack-filling versus reconstruction, for example, are compared on an equal footing (assuming, that is, that all costs and benefits are properly adjusted to a common-year basis of comparison -- see Chapter 8).

PRIMER ON PROCEDURES AND TECHNIQUES

Although executives need to rely upon experts from various fields to conduct valid cost analysis for economic evaluation, certain principles should be mastered in order to provide effective challenge and review. These are discussed below.

Capital Expenses

Capital costs should be expressed in cash terms. This is consistent with private sector practice of investment appraisal based upon the principles of discounted cash flow (DCF). The DCF approach is based upon inflows and outflows of cash and not on the accrual concepts of revenue and expense accounting. Thus no adjustments should be made to the cash flows for the periodic allocation of the asset cost known as "depreciation expense" (which is not a cash flow). Under the DCF approach, the most reliable method of evaluating the productivity returns of public investment, the capital cost of a 10 mile roadway constructed over three years should be regarded as lump sum outflows of cash over a three year period. It would thus be wrong to include depreciation over the life of the road in the economic evaluation since doing so would double-count the capital costs.

Disruption Costs

Certain projects cause delay and environmental intrusion during their construction period. These costs should be included in the economic evaluation.

Annual Incremental Operating and Maintenance Costs

Once complete, a new or improved facility may require on-going operating and maintenance expenses. Only those expenses that arise as a direct result of new investment should be included. Costs that would have been incurred in any case must never appear as part of an economic evaluation of transportation policies and investments.

User Costs and the Costs of Congestion Pricing

Some policies and projects can entail additional costs for a system's users. Any evaluation of "electronic highway" investments, for example, would need to account for the cost to vehicle owners to equip with the necessary on-board electronic equipment.

In an analogous way, demand management schemes that employ congestion pricing need to account for any lost economic value incurred by those who pay more and by those who diminish their use of the system. This lost economic value is the economic cost of a congestion pricing policy. It can be measured as the difference between what users' previously paid and the price paid as a result of congestion pricing. Known in the jargon as a "loss in consumer surplus," a fair assessment of congestion pricing should not fail to recognize the cost side of the issue.

Recent benefit-cost studies of congestion prices for airports find consistently that the economic benefits (measured in terms of time savings for aircraft that remain in the system after imposition of the fee) exceed the costs (measured in terms of lost economic value from transportation to those paying the higher fee or choosing not to use the airport during the peak period). Studies do indicate that such fees are superior to new capacity; they do imply, however, that new capacity *together with* congestion fees can represent a highly productive transportation policy for highly congested systems.

Environmental Costs

Though more uncertain than other kinds of cost, environmental costs can be analyzed in economic terms (see Box 16).

More often than not, it is objections of an environmental nature that cause delay in transportation investment or even end the prospect of certain policies taking hold. Recent developments indicate that by estimating the economic value of environmental costs and thus placing them in the broader context of economic returns to transportation generally, a greater public understanding of the net economic benefits of transportation can be fostered. This in turn can help foster consensus and end deadlocks.

PRIMER ON GOOD PRACTICE AND COMMON ERRORS

Good practice in the identification and evaluation of economic benefits and costs in establishing the productivity and growth potential of transportation policies requires many years of accumulated experience; executives should make sure that those conducting the evaluations possess the necessary skills to do so properly.

At the same time, executives require a means of monitoring, challenging and reviewing such evaluations to ensure adherence to appropriate concepts. Boxes 17A and 17B provide a comprehensive synopsis of some of the most common questions and conceptual errors in the conduct of economic evaluation. Presented in the form of a common scenario, the check-list is intended to provide executives with a basis for scanning study plans, drafts and final reports and for reviewing the conduct of evaluations with practioners.

PRIMER ON TECHNICAL LANGUAGE AND ITS INTERPRETATION

Here again, executives and decision makers alike should expect practioners to present their results in every-day language while sustaining high technical standards, policy, and decision making process (as discussed further in Chapter 9).

BOX 16

CASE STUDY

The Evaluation of Environmental Costs
The Case of Aircraft Noise

STRATEGY 2 - PARALLEL RUNWAY DEVELOPMENT, 1988-2018

NOISE COST CATEGORY	Present Value (in millions of 1988 $)		
	VANCOUVER	RICHMOND	TOTAL
Property Depreciation	12	4	16
Lost Houscholder Surplus	4.8	2.2	7
Noise Annoyance	10.6	2.6	13.2
Moving Expenses	2.4	1.0	3.4
Insulation of Schools and Care Facilines	1.9	1.9	3.8
TOTAL NOISE COST	31.7	11.7	43.4

A Benefit-Cost Analysis of a new runway for a major international airport used an economic model to assess the economic cost of additional noise for residential neighborhoods. As shown in the Table, five distinct cost categories were considered: "lost householder surplus" refers to reductions in the selling price of those who move because of noise relative to their minimum expected selling price before the advent of additional noise.

The analysis concluded the additional noise would result in total economic costs of $43 million over 20 years, or about $7,200.00 per household affected, on average. This amount compares with an estimated $4 billion in projected economic benefits due to reduced congestion.

SOURCE: Transport Canada

BOX 17A

DECISION MAKER'S GUIDE TO COMMON ERRORS IN ECONOMIC EVALUATION

Hypothetical Project: Procedures
(see Box 17B for comments on Procedures)

Consider the following scenario. A local planning authority has developed a range of road and transit investment options to relieve a mounting congestion problem in a suburban community. To help ensure that the investment maximizes economic returns under its jurisdiction, the authority has conducted a Benefit-Cost Analysis and an Economic Impact Study.

Benefit-Cost Study

1. Allowance has been made for changes in the general price level, with special reference to projected inflation in transit equipment prices and the cost of highway construction labor.

2. System capacity for each option has been determined from stated engineering standards based on threshold demand-to-capacity ratios; demand projections were based on the assumption of constant fares and other user charges over the day and the year.

3. Anticipated increases in the value of land relative to other prices have been taken into account as a benefit of the various options.

4. Carefully recorded average auto operating costs have been used to calculate the benefits of improved speeds and flow over the suburban street system.

5. Since the selected option will be partially financed through borrowing, interest payments on borrowed capital have been included in the costs for each option.

6. Grants to the local municipality from the state and federal government have been excluded from the costs since only costs net of these amounts would be paid for by the municipality itself.

7. In addition to accounting for lump sum capital outlays in the early years of the project, the analysis includes depreciation as part of the on-going operating costs.

8. Benefits include the value of direct jobs associated with the construction and operation of each option and an assessment of the multiplier effects of income and spending generated by the project on unemployed resources.

9. Certain options require a more skilled labor force than other options; these above-average job opportunities, manifested by an above wage rate, have been included as a benefit of these options.

10. The community in question is located near the Mexican border and wages paid to immigrant labor have been subtracted from total costs.

BOX 17A (continued)

DECISION MAKER'S GUIDE TO COMMON ERRORS IN ECONOMIC EVALUATION

Hypothetical Project: Procedures

1. Certain options generate more tax revenues to the municipality than others, and these revenues have been included in the benefits of each investment alternative.

2. All options have been ranked according to their estimated internal rate of return and the top ranked option recommended for implementation.

Economic Impact Study

Since a transit solution emerged as the preferred option, the planning authority also commissioned a Macro-Economic Impact Study to identify the aggregate economic implications of a transit system for the regional economy and explain these impacts to the Council and the public at large. The study had the following attributes:

1. An estimate of the number of direct jobs associated with the proposed transit system was developed and used in conjunction with a regional input-output model in order to identify the indirect effects associated with the purchases of goods and services from the suppliers to the transit system and the induced effects resulting from the spending of incomes received from the project or from later rounds of spending.

2. The direct, indirect and induced impacts were all found to be substantial and the project thus received additional endorsement and encouragement from the Planning Authority.

BOX 17B

DECISION MAKERS'S GUIDE TO COMMON ERRORS IN ECONOMIC EVALUATION

Hypothetical Project: Comment on Procedures in Box 17A

Benefit-Cost Study

1. Anticipated changes in the general price level should be ignored in benefit-cost analysis to enable the analyst to focus on the benefits and costs in real, instead of nominal, terms. No allowances for anticipated inflation or deflation should be made.

2. Although engineered design standards can provide a useful starting point, final system capacity should be determined from economic criteria (benefits and costs). And even if peak or seasonal pricing is not to be implemented in practice, failure to test the implications of shadow prices on scarce peak capacity can sharply diminish the usefulness of the analysis as a guide to the economic value and productivity of the projects in question.

3. Even if land is anticipated to increase in value relative to other prices, it is wrong to include the increase in relative value as a benefit without taking into account increases in opportunity costs associated with keeping the land in the project.

4. Allocative efficiency requires the consideration of marginal, not average, benefits and costs. For example, in calculating the operating costs of a new highway, marginal operating costs saved on alternative routes due to reduced traffic should be subtracted.

5. Interest payments of borrowed capital, while being a financial outlay, have no significance as far as the economic costs of a project are concerned since the real resources used -- labor, material, equipment and so on are the same regardless of the source of financing.

6. It is total resource costs that are relevant from a productivity and economic point of view and all grants should thus be accounted for in the analysis.

7. Depreciation is strictly a bookkeeping device. To include depreciation on top of lump-sum capital costs will exaggerate real costs.

8. The inclusion of direct jobs as a benefit is incorrect unless it has been shown that such jobs are incremental to the national economy at large. Such a determination requires an impact or input-output framework with two simulations, one with and one without the project in question. Since benefit-cost analysis involves comparing general welfare with and without a given project, the induced employment of otherwise-unemployed resources should not enter the calculations if it would have been generated by alternative expenditures displaced by the project.

BOX 17B (continued)

DECISION MAKER'S GUIDE TO COMMON ERRORS IN ECONOMIC EVALUATION

Hypothetical Project: Comment on Procedures in Box 17A

9. If it can be established that labor was under-utilized in alternative use, then wages paid by the project exceed the social opportunity cost of labor and thus labor benefits can be claimed for the project. However, the wage differential may simply be the result of different skill compositions, with the project hiring a higher proportion of skilled workers.

10. The fact that a project draws on immigrant labor clearly should not make it more attractive. Traditional benefit-cost analysis focuses on the effects of a project on total physical production and consumption possibilities, given the stock of resources in the economy. With immigration, the stock of resources increases, thus automatically expanding the production possibilities, but the consumption opportunities for the United States do not increase.

11. Transfer payments do not affect total production or consumption possibilities; they merely make someone better off at the expense of others and therefore should not be included in benefit-cost calculations.

12. The fundamental criterion for choosing among investment projects is the maximization of net present value. Ranking projects on the basis of either internal rates of return or ratios of benefits to costs may lead to sub-optimal choice.

Economic Impact Study

1. Two economic impact simulations must be conducted, one with and one without the project.

2. Only if the two simulations indicate a net gain can the economy said to be more productive and better off.

CHAPTER 8

PRESENT VERSUS FUTURE: THE IMPORTANCE OF DISCOUNTING

Alternative investment opportunities offer benefits and incur costs at different rates over time. Consumers are not indifferent between benefits of a public investment that are realized immediately and benefits that are realized in some future year. The latter benefits are less valuable because they are not available immediately for either consumption or reinvestment. Unless the economic implications of alternatives are presented in a way that accounts for the time-related value of benefits (and costs), decision makers cannot make meaningful, well-considered choices. The technique known as "discounting" is the only means available to facilitate comparisons among projects whose benefits and costs accrue at different rates. While executives need not master the mechanics of the discounting technique, they need to recognize situations in which the technique is absent or inappropriately applied.

PRIMER ON STRATEGIC PRINCIPLES

Making the effects of projects comparable requires converting the dollar estimates of future effects into equivalent current values. From today's vantage point, future receipts and payments are worth less than the same amounts due or payable now, not because of inflation, but because in current resources they require less than their face value. For example, at a 10 percent interest rate, $2 seven years into the future is worth only $1 today, simply because a dollar invested at a 10 percent interest rate will double in value in seven years. Discounting techniques translate future receipts and payments into an amount that, if set aside now at expected long-term interest rates, would cumulate to the future amounts. This allows all costs and benefits to be considered in terms of current opportunities. That is, discounted present values reflect (i) current opportunities forgone in undertaking to pay future costs, and (ii) current resources made available by future benefits.

In business, these more sophisticated practices already prevail in analyzing investment opportunities. By the early 1970s, firms that were regularly making large investments had generally adopted appraisal methods that compare discounted costs and revenues. In the public sector, these techniques are no less relevant.

Discounted Present Values Reflect Current Opportunities Forgone in Undertaking to Invest

Although society is willing to forgo current consumption to some extent in order to reap future gains, a discount rate that is too low will encourage too much investment. Conversely, a discount rate that is too high will penalize expenditures with future benefits. For this reason, proponents of investment may be tempted to use lower rather than higher discount rates and in this way down-play the value of current opportunities forgone in making an investment. Those opposed to investment, by contract, will favor higher discount rates.

The Social Opportunity Cost of Capital

A danger in understating the discount rate, however, is that public sector investments may be promoted that displace more productive investments that are possible in the private sector. As a rule, public investments, programs and regulatory actions should not be undertaken unless they are expected to earn more than high yielding private sector returns. It is thus important that the discount rate used in the economic evaluation of transportation policies and investments be at least equal to the "social opportunity cost of capital" -- the marginal return that funds would yield if invested in industry.

Expressing the Discount Rate in Constant Dollars

To ensure that present values reflect the *real* resource value of opportunities forgone, the discount rate should be expressed in real, not nominal dollars. This means that the impact of inflation on interest rates should not be included and that all benefits and costs should be expressed in dollars of constant purchasing power.

Executives are often engaged in financial as distinct from economic analysis and it is important to recognize that different analytic principles apply in the use of discount rates. Once the economic justification of a policy has been established, subsequent financial decisions may be required such as whether to purchase or lease a facility. In the economic justification of the program, the executive would be interested in the present value of the resource costs associated with the production, operation and maintenance of the facility, a consideration that is independent of inflation. In the lease-versus-purchase decision, however the government is interested in minimizing its financial exposure over time and inflation becomes a relevant consideration. For this reason, financial analysis should use prevailing current-dollar discount rates in the computation of present values.

PRIMER ON PROCEDURES AND TECHNIQUES

The federal Office of Management and Budget recommends the use of a real rate of discount of 10 percent. The 1990 Survey of Current Practice finds that state and local analysts tend to use this rate as well.

Executives should note, however, that the projected 1993 federal, state and private 10-year borrowing rate, according to the Congressional Budget Office, is between 3 percent and 4 percent. This implies that use of the 10 percent figure (which has been the OMB recommendation since 1972) could well lead to significant under-investment. For example, a projected project-related benefit of $20 million in 29 years time, discounted to the present day at 10 percent, is worth $1.2 million (see Box 18). When discounted at 3 percent, however, its value is $8.5 million, more than seven times higher. Since the benefits of transportation investments extend much longer into the future than the costs, the impact of using the higher

OMB discount rate is to understate the real value of transportation's net benefits to society.[41]

Another, more philosophical yet equally important warning is in order. Transportation investments are very long-lived and most people (including economists) believe that discounting undervalues the distant future. Whereas $20 million of net benefits in 29 years time has a present value of only $1.2 million (assuming a 10 percent rate of discount), another $20 million in year 58 would be worth a mere $75,000.00 today! Most reflective people would not accept that perfectly standard answer. The resolution to this problem is not to abandon the discounting concept -- it is the only means available to deal with very important questions of the time-value of money. Rather, executives should remember that not all of the long-term benefits of investment can be anticipated (such as the impossibility of foreseeing just-in-time inventory as a benefit of the Interstate Highway System -- see Chapter 6); this means that some form of Indicative Planning (Chapter 3) will always be needed to guide long-term policy and program development.

PRIMER ON GOOD PRACTICE AND COMMON ERRORS

A critical function of the executive is to ensure that discounting procedures are actually used in the economic evaluation process. As shown in Box 19, the 1990 Survey of Current Practice indicates that transportation projects are very rarely evaluated with adequate discounting techniques. This dampens the likelihood of finding the most productive transportation investments and places misleading information before decision makers.

PRIMER ON TECHNICAL LANGUAGE AND ITS INTERPRETATION

Executives and decision makers should be familiar with three key terms.

The Social Opportunity Cost of Capital

The social opportunity cost of capital is the estimated rate of return on capital in its next best use relative to the investment in question. It can be viewed as the cost to the standard of living entailed in the investment of capital dollars rather than making them available to society for other purposes. Investments should thus equal or exceed the social opportunity cost of capital.

[41] Some analysts use a discount rate corresponding to the rate of interest that a state's "Pooled Money Investment Fund" earns in the private lending market. This usually lies between the OMB's rate of 10 percent and the borrowing rate of the state (which some argue to understate the social opportunity cost of capital). This rate may be a better reflection of the value of capital funds to the private sector than either of the two other alternatives discussed here and is thus a sound basis for assessing the desirability of public investment programs and projects.

The Social Discount Rate

The number used to convert both benefits and costs occurring in future years to their equivalent value today is the social opportunity cost of capital.

Discount Factor

Derived from the discount rate according to the formula $1/(1 + i)^t$ (where i is the social discount rate and t is the index of the year in which the cost or benefit will occur) the discount factor is the factor applied to each benefit and cost in order to convert it to its present value.

BOX 18

CASE STUDY

How to Compute Discount Factors

General Formula

$$\text{Discount Factor} = \frac{1}{(1+i)^t}$$

where i is the discount rate;
and t is the year

Example

To calculate the discount factor of the 29th year with a 10 percent discount rate (use a hand calculator):

1. Compute the Value of: $(1 + i)$

$$(1 + 0.10) = 1.10$$

2. Compute the value of: $(1 + i)^t$

$$(1.10)^{29} = 15.8631$$

3. Compute the value of: $\frac{1}{(1 + i)^t}$

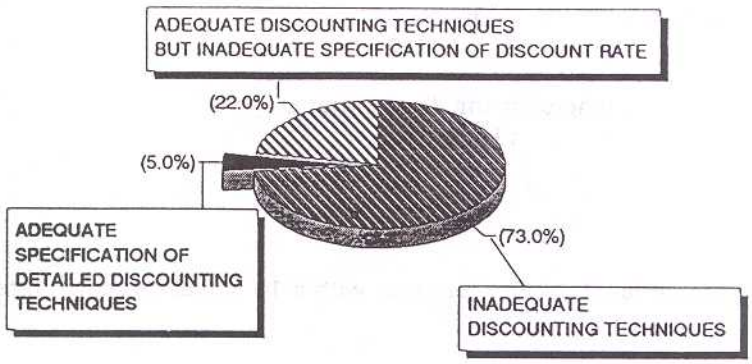
$$\frac{1}{15.863} = 0.06304$$

The discount factor for year 29 at a ten percent discount rate is 0.06304. To apply this discount factor, multiply it by the constant dollar benefits or costs in year 29. For example, if the total benefits in year 29 are estimated at $20,000,000 the present value of this benefit is 20,000,000 times 0.06304 or $1,260,788.

BOX 19

SURVEY OF CURRENT PRACTICE: 1990

Treatment of Timing and Discounting



Only five percent of all studies reviewed in the Survey of Current Practice applied proper discounting techniques. Failure to do so means that decision makers are not presented with meaningful information regarding the comparative merits of alternative policies and investments.

CHAPTER 9

STRATEGIES FOR COPING WITH RISK AND UNCERTAINTY

A great many uncertainties have been found to enter into the conduct of an economic analysis for major transportation policy and investment choices. Some of these are technical and involve forecasts about the future, while others reflect value judgements about economic and social factors and about peoples' willingness to bear more pollution or noise or increased delay and less economic development.

All executives are mindful of the fact that if one thing is cèrtain about economic evaluation it is that virtually every important forecast will be wrong to some degree, simply because the future is unknowable with complete certainty. The wider community too is well aware of such uncertainties, which adds to the difficulty of finding public consensus on sensitive transportation policy issues.

How then can decision makers and technical analysts evaluate the pros and cons of their investment choices? How best can the community compare forecasts about the adequacy of existing facilities with the merits of improvements, including the construction of new capacity, given the multitude of uncertainties about the future? In the midst of technical uncertainty *and* discordance in the community over economic, environmental and social goals, how can transportation policy making be managed so as to foster consensus and progress?

PRIMER ON STRATEGIC PRINCIPLES

Recent extensions of a family of techniques called risk analysis have demonstrated promise in fostering understanding and consensus among decision makers and the community at-large by involving a broad spectrum of stakeholders in the analytic process itself. The principles are two-fold:

- People do not believe single, one-shot forecasts of the economic implications of a given policy or investment. Nor do they see any practical value in "scenarios" that give no indication of how likely each is to materialize. Like modern weather forecasting, risk analysis recognizes that people, including decision makers and members of the general public, are more comfortable with a probability forecast -- i.e., a "20 percent chance of rain" -- than with the assertion "it will not rain...".

- To generate their confidence in the analysis and the decision making process, stakeholders, including decision makers and members of the public, need to be involved from the ground-up, including base case design; the scoping of alternatives; the analytic process; and the decision making procedure.

PRIMER ON PROCEDURES AND TECHNIQUES

Grounded in these principles, risk analysis combines probability methods of specifying assumptions and making forecasts with modern methods of group dynamics to foster consensus. Typically, risk analysis follows a four-step process, as follows:

- The base case and alternative courses of action are developed at either a policy, program or project level;
- At each stage in the analysis, probability distributions are developed for each and every assumption and judgement in the engineering and economic analysis;
- Panels of stakeholders are formed, including executives, decision makers and outside experts and specialists. The panels scrutinize the probability ranges and make adjustments to them. The panel is encouraged to reach a consensus on the probability range for each assumption before moving on to the next. Separate panels are formed for each aspect of the process (capacity analysis; demand forecasting; economic assumptions; environmental analysis and so on -- see Box 20);
- Computer simulations combine all probability ranges to produce a probability range of the economic return associated with the alternatives; their environmental implications; and other information.

The outcomes thus reflect broad community involvement at each stage of the planning and evaluation process and all projections are stated as probabilities. As a result, experience indicates that the community often comes to accept the analysis rather than engage in long and acrimonious debates over assumptions and forecasts. This, in-turn, elevates the debate to policy choices and fosters consensus and decision.

In 1989, the Toronto Transit Commission conducted the risk analysis process with regard to transportation policies for people with disabilities and achieved consensus in a highly controversial policy area. In 1988 the Metropolitan Council of the Twin Cities used risk analysis and gained consensus and decision with regard to airport expansion. And in 1990, the Arizona Department of Transportation used risk analysis to reach consensus on aspects of a major highway bond issue.

PRIMER ON GOOD PRACTICE AND COMMON ERRORS

As shown in Box 21, the 1990 Survey of Current Practice found that only 20 percent of the evaluations examined used any form of risk analysis. Moreover, none used risk analysis in a public setting. Good practice in the 1990s would be served with applications of these techniques.

PRIMER ON TECHNICAL LANGUAGE AND ITS INTERPRETATION

The language of sensitivity and risk analysis is broadening to include concepts of public involvement in the process of assessing choices and in considerations of how best to manage change in the light of known uncertainties. Executives need to foster this concept as well as the narrower, though critically important, technical aspects of risk analysis.

BOX 20

CASE STUDY

Risk Analysis and Consensus Building

Six Risk Analysis Panel Sessions were held during the course of a major airport expansion study. Experts and stakeholders helped shape the strategies to be considered and the assumptions and judgments to be made in conducting the economic evaluation.

The panel sessions spanned six aspects of the study, as follows:

- **Session Number One** -- This Session reviewed a wide range of specific development alternatives and identified those to be considered as part of the Benefit-Cost Analysis;

- **Session Number Two** -- This Session assessed the demand models and assumptions and the probability of the various assumptions turning out as expected;

- **Session Number Three** -- This Session assessed the capacity models and assumptions and the probability of the assumptions turning out as expected;

- **Session Number Four** -- Participants assessed the structure and logic of the economic models, the validity of individual assumptions and the probability of assumed values of passenger time savings, aircraft fuel savings, airport growth-related employment and other key economic forecasts being valid as a basis for conducting the economic evaluation;

- **Session Number Five** -- Participants, including residents of noise-affected communities, assessed the rate of property depreciation and the level of nuisance costs associated with aircraft noise and helped establish the probability of the assumptions turning out as projected; and;

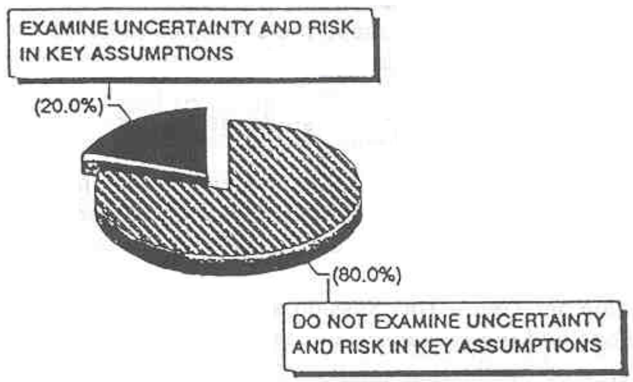
- **Session Number Six** -- Participants assessed the results stemming from each of the five previous sessions.

On the basis of detailed research and analysis, together with expert and stakeholder scrutiny of alternative strategies and technical assumptions, the report estimated the economic performance of alternative development strategies for the Airport on a probability basis. The Risk Analysis identified the probability that the actual net present value of a given strategy would differ from its estimated value. This information was then used to develop community consensus around a long-term development strategy for the airport that provides an economically efficient and socially acceptable solution while minimizing the risk of either over- or under-investment.

BOX 21

SURVEY OF CURRENT PRACTICE: 1990

Treatment of Risk and Uncertainty



Only one-fifth of all evaluations examined in the 1990 Survey of Current Practice used some form of sensitivity on risk analysis.

ANNEX A

INDUSTRIAL RESTRUCTURING ANALYSIS

EXPLORING AND MEASURING INDUSTRY-RELATED PRODUCTIVITY IMPACTS OF TRANSPORTATION POLICIES

Part III of the Technical Report provides a newly developed technical procedure, called Industrial Restructuring Analysis, for quantifying the industry-related productivity benefits associated with major changes in the transportation system. It also provides a detailed approach to collecting the information needed and a computer program designed to assist in the computations. These techniques are in their infancy and should be used with caution and prudency.

The consultative process recommended, however, involves a brief questionnaire for industry managers that will provide useful insight, whether or not the full computation is attempted. For executives and decision makers, just reviewing the questions will provide a fuller understanding of the potential productivity implications of major policies aimed at improving the reliability of the transportation system. A next step would be to use the questions as a basis for establishing a dialogue with industry. Thereafter, executives can decide whether to attempt the quantification procedure based upon the extent to which actual policies and priorities might shift in response to the results.

QUESTIONS FOR INDIVIDUAL FIRMS

The best and only source of information about how road improvements will affect transportation using firms, is the firms themselves.

It is important in gathering information from firms that questions be reasonable and in terms that firms will be able to answer without excessive effort.

Answers to the following questions would answer the estimation needs of the model:

- How many vehicle-miles (or other unit of choice) do vehicles operated by your firm travel annually?
- What proportion of these vehicle-miles are travelled within the affected region?
- What is your total annual expenditure on drivers' wages, fuel, vehicle maintenance, etc? (List set of direct cost measures.)
- If these road improvements are implemented, and assuming that your volume of business stays at past levels:
    - What savings do you anticipate on the direct costs (listed previously)?
    - What changes in your operations, if any, would you undertake to take advantage of these improvements?
      Are you likely to adopt inventory reductions?

  - Reduced number of stocking points?
  - Increased application of just-in-time inventory practices?
  - Changes in fleet composition?
  - A new production or distribution technology?
  - A new technology sooner than previously planned?
  - Other changes in operations?

- What further cost reductions do you anticipate from these changes in operations?

- What changes in vehicle miles (or other unit) do you anticipate as a result of these changes, given the same volume of business as you currently have?

Transportation intensive firms could reasonably be expected to answer these questions. Making trade-offs between stocking points and transport expenditure is a key feature of cost control in modern companies. The questions all focus on operational cost savings available to the firm, given its current volume of business. This reduces questions to an entirely technical level. Firms are not requested to speculate on how firm or industry demand changes. The basic requirement is limited to showing firms the new alternative plans and asking, in dollars and cents, how it will likely benefit them.

A WARNING

It is important to note that questions of the kind posed above can lead to exaggerated claims -- a phenomenon called, aptly, "non-commitment survey bias." As implied in the term, where benefits might be forthcoming from a policy change, survey respondents are apt to claim support for them because nothing needs to be sacrificed (such as a commitment to higher taxes or fees) in responding to a mere survey. For this reason, Industrial Restructuring Analysis also involves integrated retrospective studies (see p. 56 earlier) and probability analysis together with consultative analysis in order to yield realistic results.

ANNEX B

Methodologies for Evaluating the Effects of Transportation Policies on the Economy

Technical Report

Supplement to NCHRP Report 342

Prepared for
National Cooperative Highway Research Program
Transportation Research Board
National Research Council

HICKLING CORPORATION
Silver Spring, MD

ACKNOWLEDGEMENTS

The research reported here was performed under NCHRP Project 2-17(1) by the Hickling Corporation, Washington DC. Christensen and Associates and Charles River and Associates were subcontractors to Hickling.

Dr. David Lewis, Partner and Chief Economist of the Hickling Corporation, was the Principal Investigator and author of the Reports. Professor Robert M. Solow of the Massachusetts Institute of Technology acted as Special Advisor to the Project, providing oversight and review at each state of the work. Dr. Laurits Christensen and Dr. Philip Schoech of Christensen and Associates and Dr. Gary Fauth of Charles River provided technical assistance, reviewed and commented on Report 342 (the Primer) and made written contributions to Supplement to Report 342 (the Technical Report).

FOREWORD

The information in this report will be of special value to transportation officials, who are interested in the relationship between transportation and the economy, and to transportation analysts, who are interested in the economic analysis methodologies and decision rules that can be applied to future capital investments to foster continued economic growth and productivity.

The recognition of capital investment as a principal catalyst of productivity, economic growth, and improved competitiveness has led transportation decision-makers to ask how best to identify productive transportation policies and investments. For private investment, market forces help ensure that the rate of capital formation is limited to profitable and productive levels and that individual investments make a net contribution to the nation's Gross National Product. In the public sector, where market forces are weak and objectives multifaceted, transportation executives and decision-makers must have access to special information about the potential for transportation policies and investment opportunities to stimulate productivity, economic growth and gains in the standard of living. Transportation officials also need information on the kind of transportation policies and investments that have growth-related characteristics and on the methods and procedures available to identify specific opportunities for productivity and growth through transportation policy initiatives and capital investments.

NCHRP Project 2-17(1), "Methodologies for Evaluating the Effects of Transportation Policies on the Economy," was initiated by Hickling Corporation, Washington, D.C., with three objectives. The first objective was to identify and describe methodologies available to analyze the relationships between transportation and the economy. Of particular interest here is the relationship between transportation investment and gains in industrial productivity and competitiveness. The second objective was to critically evaluate the methodologies and the state of knowledge resulting from their use. This objective also asked how transportation agencies use alternative methodologies from both a technical and decision-making perspective. The third objective was to develop a primer for transportation executives and decision-makers that documents what is known about the relationship between transportation and the economy and provides guidance on the use of economic analysis to identify policies and investments with the potential to foster growth and productivity.

The results of Project 2-17(1) are presented in two reports: NCHRP Report 342, "Primer on Transportation, Productivity and Economic Development," and "Supplement to NCHRP Report 342 -- Primer on Transportation, Productivity and Economic Development -- Technical Report." The Supplement to Report 342 is designed for the practicing transportation analyst. It provides the technical background for the material in Report 342. The Technical Report presents a new approach, developed under Project 2-17(1), that enables the analyst to identify and quantify the logistics-related benefits for private firms that stem from transportation investments.

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ACKNOWLEDGEMENTS

The research report here was performed under NCHRP Project 2-17(1) by the Hickling Corporation, Washington DC. Christensen and Associates and Charles River and Associates were subcontractors to Hickling.

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SUPPLEMENT TO NCHRP REPORT 342

TECHNICAL REPORT

PART I

TECHNICAL PRINCIPLES

CHAPTER 1

INTRODUCTION

Project 2-17(1) developed a Primer to guide infrastructure decision-makers and practitioners in the selection and use of methodologies for ascertaining the influence of transportation on the economy. Through the Primer, its users will need to gain an understanding of:

- The economic objectives of infrastructure investment. The Primer helps decision-makers and practitioners target their planning activities in relation to the economic objectives they, and the nation, desire to achieve;

- The close relationship between objectives and methodology and how the choice of methodology depends entirely upon the choice of economic objectives. The Primer should ensure that decision-makers and practitioners select the best methodologies in relation to their economic objectives for infrastructure investment;

- The capability of each methodology to measure in full all relevant impacts given the economic objectives of interest. In preparing the Primer, we needed a complete understanding whether and in what way existing methodologies require adaptation in order to accommodate newly discovered relationships between transportation and the economy (such as public capital formation as a catalyst of private sector productivity); and

- The valid and effective application of appropriate methodologies. While the Primer does offer a textbook-style step-by-step technical roadmap for each methodology, it must serve decision-makers and practitioners with a practical guide to the effective application of appropriate methodologies.

We also require a thorough understanding of the characteristics of current practice in establishing the economic objectives for infrastructure investment, in selecting evaluation methodologies and in applying methodology. This understanding is needed to ensure that the Primer is targeted to areas of essential and practical need in the field.

To establish the basic understanding needed as a foundation for preparing the Primer, Part I addresses principally the first four questions above. It is emphasized that, as anticipated in the research design, new theoretical advances and advances in application are required in addressing the third question; Part I develops these advances and thus presents technical material. While essential to Part I of the Project, the material does not appear in technical form as part of the Primer itself. Non-technical language (and development of the language template) thus remains a high priority element of the research, and is given weight in Part I. Due to the development nature of Part I, however, the language template is developed fully in Part II of this Technical Report.

Part I also presents an Evaluation Plan for Part II and thus addresses the fourth question posed above. Part I reports the results of preliminary evaluation activity as a guide to the evaluation-design.

PLAN OF PART I

Part I is presented in six chapters. Chapter 2 recognizes that the appropriate methodology in any given situation depends upon the economic objectives being pursued. It develops a taxonomy of objectives for transportation infrastructure investment and identifies investment policy criteria that are of special relevance to the question of productivity and economic growth. Chapter 3 then develops and analyzes an inventory of methodological approaches that are consistent with the objectives established in Chapter 2.

Chapter 4 focuses on those methodologies of special relevance to productivity and economic growth at the national, state and local level. The Chapter examines the risk of sub-optimal infrastructure investment in the use of conventional methodologies. Where such risks are apparent, the Chapter asks whether they stem from underlying structural (theoretical) weaknesses in methodology or weaknesses in application. The Chapter develops the formal theoretical framework needed to address this question rigorously and begins to shape the methodological advances needed to resolve the weaknesses uncovered.

Chapter 5 develops the basic criteria against which current practice can be assessed in Part II (taking into account the requirements developed in Chapter 4). Chapter 5 develops criteria for the correct identification of economic objectives; the correct selection of associated methodology; and the correct application of methodology. The evaluation criteria also enters significantly into the Primer itself, guiding users in the correct selection and use of methodology.

Finally, Chapter 6 presents the recommended Evaluation Plan for implementation in Part II.

CHAPTER 2

UNDERSTANDING THE ECONOMIC OBJECTIVES OF INFRASTRUCTURE INVESTMENT

Different methodologies measure different aspects of the interrelationship between transportation and the economy. The choice of methodology in infrastructure evaluation and decision-making thus rests critically upon what aspect of economic activity policy is attempting to influence. The fact that an Impact Study for an airport or highway project forecasts a given number of direct, indirect and induced jobs, for example, does not mean that its construction would foster the objective of improved productivity and growth in national or regional output: A Rate of Return study would be needed to ascertain the latter. And if the Rate of Return study indicated that economic growth would result from the investment, this in itself would say nothing about the project's implications for peoples' standard of living: An answer to this question would call for a Social Benefit-Cost Analysis.

It must also be recognized that the specification of economic objectives for infrastructure investment is not always easy or obvious--indeed, our review indicates that it is a source of considerable confusion. There is growing concern, for example, that transportation investment policies are not providing the necessary level, type or quality of service required to maintain or improve national productivity and growth. Does this mean, however, that enhanced productivity and growth are valued for their own sake? Or is growth a means of achieving the broader economic purpose of improved living standards? Failure to recognize this distinction can result in policies that promote investment-led growth at the sacrifice of current consumption and possible social and environmental risks that diminish living standards. The related methodological problem is that a mis-specification of economic objectives can lead to the choice of methodologies which in effect answer the wrong question and promote inappropriate policies.

To select the appropriate methodology in any given situation, policy makers and practitioners thus require;

- A clear understanding of the various economic objectives that infrastructure investment may serve to promote;
- A clear understanding of the economic objectives implicit in the use of alternative evaluation methodologies; and
- A clear and valid framework for selecting desired economic objectives and identifying the correct methodologies for use in measuring their achievement.

PLAN OF THE CHAPTER

The remainder of this Chapter provides a taxonomy of objectives and guide to the selection of the appropriate objective from the viewpoint of achieving desirable levels of productivity and economic growth through transportation investment. This analysis will be expanded in Part II and provides a foundation for guidelines in the Primer.

A TAXONOMY OF ECONOMIC OBJECTIVES FOR INFRASTRUCTURE DEVELOPMENT

From theoretical and applied economic literature, a range of economic objectives can be identified that are discrete in the sense that their achievement calls for the use of identifiably different choice and ranking (or "rationing") criteria. A "choice-criterion" is a quantitative measure used to ascertain whether a project advances the nation or region towards its objective and is thus an acceptable investment (the term "acceptance criterion" is also used in this context). Choice criteria are relevant when it can be assumed that all acceptable projects are to be financed. Ranking and rationing criteria are employed when budgets are limited and only those investments making the greatest contribution to their economic objectives can be financed.

In our preliminary evaluation of current practice, we have found it necessary to induce local goals from the adopted choice criteria. This is because evaluations are often imprecise in stating the economic objectives of transportation projects. We find, however, that the adopted choice criteria are often inconsistent with stated objectives--criteria are often selected that measure the achievement of objectives other than those stated by decision-makers. The findings of our preliminary evaluation are outlined here as a basis for establishing the full evaluation plan in Chapter 5.

Seven discrete economic objectives can be identified in the economics literature. The taxonomy of economic objectives for infrastructure investment enters the Primer as a "roadmap" to steer decisionmakers and practitioners to the technically correct objective given their underlying policy purpose.

The seven possible objectives may be stated as follows;

- Growth in total employment;
- Growth in productivity;
- Economic growth;
- Increased economic welfare;
- Change in the distribution of income;
- Regional transfers; and
- Sectoral transfers.

Growth in Total Employment

Total employment refers to the total number of remunerative jobs at either the national or defined subnational geographically defined area (a state, a region or a city, for example).

Acceptance and Ranking Criteria. As shown in Table 1, the choice criterion under the employment objective accepts any project that creates employment and jobs; the ranking criterion places those projects with the greatest employment-creation possibilities above others. As discussed later, the validity of this objective is highly questionable from an economic standpoint since labor is an economic cost, not an economic benefit, of achieving growth.

Employment maximization fails, for example, to ensure that labor resources are channelled into their most productive use (see discussion below on welfare maximization).

Preliminary Evaluation. Our preliminary evaluation of current practice finds, however, that many infrastructure evaluations use the employment criterion and thus implicitly (and in many cases, unknowingly) adopt the employment objective when economic growth and economic welfare represent the decision-makers' primary goals.

TABLE 1: ALTERNATIVE ECONOMIC OBJECTIVES FOR TRANSPORTATION INFRASTRUCTURE AND RELATED PROJECT SELECTION AND RANKING CRITERIA

OBJECTIVE	PROJECT SELECTION CRITERION	RANKING AND RATIONING CRITERION
Growth in total employment.	Any project that creates employment.	Projects creating the most employment.
Growth in productivity.	Any project with a higher rate of return than that being realized in the private sector.	Projects with the highest rate of return.
Economic growth.	Any project with a positive rate of return.	Projects with the highest rate of return.
Economic welfare.	Any project with a positive net present value (assuming the social discount rate).	Projects with the highest net present value or the highest net present value per dollar of capital invested.
Distribution of income.	Any project with a higher rate of return than the social discount rate, where benefits and costs to lower income groups are weighted more highly than those to higher income groups.	Projects with the highest net benefit or highest net present value per dollar per capital invested, where benefits and costs to lower income groups are weighted more highly.
Regional transfers.	Any project with a positive net present value (assuming the social discount rate) where benefits and costs beyond regional boundaries are not counted.	Projects with the highest net present value or highest net present value per dollar of capital invested, where benefits and costs beyond regional boundaries are not counted.
Sectoral transfers.	Any project with a positive net present value (assuming the social discount rate) where benefits and costs to other sectors are not counted.	Projects with the highest net present or highest net present value per dollar of capital invested, where benefits and costs to other sectors are not counted.

Growth in Productivity. Productivity is defined as the value of production of marketed goods and services per hour worked; items for which there are no market prices, such as time savings, leisure and the current state of health, are not included in the definition of productivity. The maximization of productivity as an objective implies a policy of achieving the greatest possible hourly production per hour worked at the national, state or local level.

Acceptance and Ranking Criteria. If productivity is chosen as the objective of public infrastructure investment, projects may be accepted if their rate of return exceeds that typically achieved in the private sector. The productivity objective will conflict with the employment objective in cases where the rate of return is achieved through reductions in labor requirements.

Preliminary Evaluation. Although improved productivity is often referred to as a goal of public infrastructure, it is rare to find the associated acceptance criterion in use.

Economic Growth

Economic growth may be defined as an increase in total production valued at market-determined prices (that is, real Gross National Product or the gross product of some sub-national geographically defined area). As in the case of productivity, items for which there are no market prices, such as time savings, leisure and the current state of health, are not included in the concept of economic growth.

The maximization of economic growth as an object of policy thus means maximizing the real-dollar production (or "output") of only marketed goods and services. This objective can be pursued at a the national, state or local level through measures that either increase total employment or increase production per hour-worked (productivity).

Acceptance and Ranking Criteria. As indicated in Table 1, the acceptance criterion for infrastructure projects under the growth criterion is any investment with a positive rate of return; where budgets are limited, projects with the highest rates of return are selected first.

Preliminary Evaluation. Reference is often made to the objective of economic growth as an object of infrastructure investment; it appears rare, however, to find rate of return calculations in use. The employment criterion, which is in far more common use, recognizes, implicitly that employment can generate economic growth; the rate of return calculation is nevertheless required in order to estimate whether individual projects will or will not foster economic growth or merely shift employment from one sector to another.

Increased Economic Welfare

"Economic welfare" is a term coined by economists. Increased economic welfare is defined to occur when a change (such as an investment in transportation infrastructure) yields economic benefits--to both individuals and firms--whose economic value exceeds the economic costs (opportunity costs) of achieving them. Cost is defined broadly to include all economic benefits and living standards forgone as a result of the investment in question.

Like production and growth, economic welfare can be measured at any geographic level. Economic welfare is distinct from the value of total production however in that the latter is restricted to goods and services that are bought and sold in the marketplace. Economic welfare, on the other hand, also accounts for items for which there is no market but that nevertheless occasion economic value in the sense that people are willing to pay to acquire them. Such items include time savings, leisure time, improved health and environmental conditions and so on.

The objective of economic welfare also accounts for the way individuals value present consumption over investment for future consumption. This is achieved through the use of a "social discount rate" --a factor that translates the value of all future costs and benefits into their present-day worth (commonly termed "present value").

Acceptance and Ranking Criteria. Any project with a positive incremental net present value may be regarded as acceptable under the welfare objective. Incremental net present value is the sum of all economic benefits over and above those likely to be achieved in the Base Case discounted to their present value at the social discount rate minus the sum of all economic costs over and above those incurred in the Base Case discounted to their present value. If the present value of the benefits minus the present value of the costs -- the **net present value (NPV)** -- is greater than zero, the investment may considered a worthwhile contribution to the economy. The "Base Case" is defined as the steps needed to make the most efficient and effective use of existing infrastructure, including small-scale capital investments, improved technology, traffic management and so on.

A positive net present value means that a project contributes positively to both productivity and growth. As an acceptance criterion, net present value rejects projects in which the value of any contribution to productivity and growth is less than the economic costs to be incurred in achieving that contribution. This is distinct in application from the growth criterion above in that it accounts for the social opportunity cost of capital. The validity of the NPV criterion thus hinges on the correct identification of the social opportunity cost of capital and the full identification of all positive contributions to productivity in the estimation of net present value. This issue is the subject of Chapter 4.

Where budgets are constrained and capital rationed, projects with the highest net present value may be ranked above those with lower net present values. Where limited budgets mean that very expensive transportation infrastructure projects are at risk of crowding out less costly high-NPV projects in a capital budget, the literature indicates that ranking projects according their ratio of NPV to total capital cost (i.e. maximum NPV per capital dollar) provides a basis for allocating limited funds. This ratio may be regarded as a means of ensuring a "balanced" capital program; in accepting projects with lower over higher NPVs, however, the rule causes a deviation from maximum economic contribution of transportation infrastructure.

Preliminary Evaluation. The net present value criterion is rarely adopted in practice, although the goal of welfare maximization is often foremost in the minds of decision-makers. Again, the employment criterion is often mistakenly embraced as the correct measure of welfare gains. In those cases where the net present value criterion is used, technical errors and mis-specification of the Base Case are common.

Where the net present value criterion is applied correctly, however, there remains the risk that certain productivity impacts are omitted, leading to an under-estimate of total benefits and a corresponding risk of under-investment. Three possible reasons would explain this risk. First, the theory of applied welfare maximization is vague with regard to the ability of welfare tests (such as net present value) to capture private sector productivity increases stemming from public infrastructure development. Second, the literature is weak in providing applied methodological approaches to measuring such impacts. And third, there is no evidence in our preliminary review of current practice that practitioners attempt to measure them. These problems are the subject of Chapter 4.

Changes in the Distribution of Income

The "distribution of income" commonly refers to the share of total output and income obtained by groups at different levels of income. Income distribution as an objective of policy indicates that a nation, or a sub-national geographic unit, may place a value on the fairness of the division of output, as well as its total value.

Acceptance and Ranking Criteria. The economic literature provides a number of techniques for measuring the distributional implications of transportation projects but few categorical criteria for judging when distribution is "optimized" from an economic point of view. As indicated in Table 1, the rigorous (though rarely used) approach applies judgemental weights to various income groups and then recalculates the net present value accordingly. Any project whose weighted NPV is positive may be regarded as economically worthwhile and projects may be ranked according to income weighted NPV.

Preliminary Evaluation. A more common approach is to examine the distributional implications of proposed investments and judge their suitability against national or local community standards. This approach is common when distribution is regarded as the principal objective of infrastructure investment; it makes no allowance for the contribution of a project to productivity or growth.

Regional Transfers

Regional transfers refer to the aim of transferring the value of production or economic welfare from one region to another. This may be a goal because of a fairness objective within the overall federal framework, or the public agency at the state or local level may prefer to concentrate on its own economic conditions, regardless of the net national impact.

Acceptance and Ranking Criteria. The rigorous approach here is to apply the net present value criterion but to restrict all projections of benefits, costs and discount rates to those in the region of interest. Less rigorous (and quite common) analysis includes the inspection of regional transfer effects on the basis of information generated from input-output analyses. While such information can offer extremely useful information about the distributional (income, regional and sectoral) impacts of prospective investments, it can only be used to judge the net contribution of projects to productivity and growth under special analytic conditions that are rarely observed in practice.

Preliminary Evaluation. Our preliminary evaluation finds that most authorities do limit their evaluations to the regions under their authority; it is rare, however, to find the net present value criterion in use. From the criteria that are applied, most regions, implicitly and apparently unknowingly, are measuring achievement of employment or other non-productivity and growth-related objectives.

Sectoral Transfers

Sectoral transfers refer to the aim of shifting wealth or economic activity from one industry to another. When valued on its own, this goal would be chosen if one sector is favored for its own sake. This could result from a view of the sector as an engine of growth, from social values (such the desire to sustain a traditional industry) or even from political clout.

Acceptance and Ranking Criteria. The rigorous approach here is to apply the net present value criterion but to restrict all projections of benefits, costs and discount rates to those in the sector or industry of interest.

Preliminary Evaluation. Here again, our preliminary evaluation finds that most authorities do limit their evaluations to the regions under their authority but rarely are they targeted to particular industrial sectors. And it is rare to find the net present value criterion in use. From the criteria that are applied it seems clear that most regions, implicitly and apparently unknowingly, are measuring the achievement of employment or other non-productivity and growth related objectives.

The Objectives of Improved Economic Living Standards and Economic Development

Technically, the economics literature does not treat the objective of "improved living standards" as a discrete object of policy with its own distinct definition. The same it true in the case of "economic development." Frequent reference to these terms in infrastructure investment decision-making, however, means that they must be given precise meaning in the context of the economic objectives that infrastructure investment are chosen to serve. Without such precision, the risk of adopting inappropriate evaluation methodologies will remain high.

Economic Standard of Living. Inasmuch as an improved standard of living relates to all aspects of daily life that occasion value to individuals, the economic welfare objective comes closer than any other to measuring the change in living standards that an investment in public infrastructure may bring about. It is thus recommended here that the Primer equate the objective of maintaining and improving living standards to the technical objective of improving economic welfare. Methodologies tied to welfare maximization would thus be recommended in cases where living standards are regarded as the ultimate objective of policy.

Economic Development. The meaning of the term "economic development" depends critically upon how the six principal objectives are prioritized; if productivity and economic growth are desired for their own sake, then any investment that creates greater output can be said to promote economic development. If, on the other hand, improved living standards are considered the ultimate purpose of infrastructure investment, greater productivity and output in themselves would not necessarily signal economic development. Here an investment would also need to achieve the welfare objective whereby the present worth of any economic costs to be incurred in the achievement of enhanced productivity and growth lie beneath the present worth of associated economic gains.

What then are the "appropriate" economic objectives for evaluating transportation infrastructure investments? This question is addressed next.

SELECTING APPROPRIATE OBJECTIVES

The appropriate economic objectives for transportation infrastructure investment are considered here in the context of national concerns regarding productivity and growth. In particular, recent economic research emphasizes the importance of both private and public capital formation to the stimulation of improved productivity and thus growth in economic output. Obviously, productivity and growth are critical to the nation's future. This does not necessarily mean, however, that the maximization of productivity and growth represent the ultimate objectives of public investment in transportation infrastructure.

Productivity and Growth: A Means or End?

Is growth to be valued for its own sake, or for its contribution to individuals' economic welfare and standard of living? This is not a rhetorical question. Growth as a national objective for its own sake has been the choice of many nations, both present and past, and implies that any infrastructure investment with a positive rate of return should be undertaken. If economic welfare is the goal, on the other hand, then the investment test is more stringent--the rate of return must be high enough to justify the sacrifice of current consumption, as measured by the social discount rate. There will be less investment under a national welfare objective than under an objective of growth for its own sake. Substantial growth can be expected under the welfare objective; it is limited however to growth that yields economic benefits in excess of the costs of achieving them. Under the welfare objective, therefore, productivity and growth represent a means to an end, where the end is maximum economic welfare and the associated standard of living.

Welfare Maximization as the Appropriate Economic Objective for Transportation Infrastructure in Enhancing Productivity and Economic Growth

Growth may be accepted as an end in itself only if the nation (or any sub-national geographic region) is willing to risk the sacrifice of certain living standards in order to expand production and output. Some analysts argue that Japan has taken this course, achieving high growth at the expense of environmental quality and certain living standards. To date, however, the recommended U.S. standard among public policy analysts and major practitioners (the Army Corps of Engineers, for example) has been to evaluate public investment decisions on the basis of maximizing economic welfare.

Preliminary discussions with Professor Robert Solow, Senior Advisor to our project, lends weight to the welfare objective. According to Professor Solow:

> "Once you make it clear that "economic growth" as an objective implies acceptance of any project with a positive rate of return, you have already discredited it. No one will accept a rule that puts the social cost of capital at zero." (See Appendix A.)

Professor Solow rejects productivity as an end it itself for analogous reasons.

It should be noted, however, that in accepting economic welfare as the prime objective of infrastructure investment, one is not dismissing the fundamental importance of public investment in promoting productivity and thus economic growth: indeed, properly applied the net present value test of welfare measures the productivity and growth implications of prospective investments (although whether all productivity impacts are measured remains an open question--see later). The welfare objective simply recognizes that productivity and growth can only be obtained at an economic cost and that the level and type of investment in transportation infrastructure should be set so as create the maximum gain in economic productivity and growth in relation to the total economic costs of their achievement.

It should also be noted that the choice of welfare maximization as the prime objective in seeking to maximize transportation's contribution to productivity and growth does not dismiss the potential relevance of other goals. Employment and sectoral and regional distribution for example, will be seen as important-and in some cases, key--aspects of many decisions. The Primer recognizes that policy makers will require information about such impacts. It is critical however that in selecting evaluation methodologies, decision-makers and practitioners recognize that techniques which measure employment and distributional impacts are inappropriate in the evaluation of infrastructure's contribution to productivity and growth.

Although national welfare has been the assumed goal of project evaluation in our schools and public debate, it is by no means clear that this is in fact the general practice in the United States. Our preliminary examination of current practice indicates that the actual selection of evaluation techniques quite often reflects goals, albeit implicitly, that are very different, such as regional or sectoral income redistribution. Therefore, one of the criteria for assessing current practice will be whether the technique chosen is appropriate for the public goal. In our preliminary investigation we find that many project evaluations today do not choose techniques for evaluation that are appropriate to their stated goals, or to the national objectives of enhanced productivity and growth.

CHAPTER 3

SELECTING THE APPROPRIATE METHODOLOGY IN RELATION TO THE ECONOMIC PURPOSE OF INFRASTRUCTURE INVESTMENT

Choosing the correct method for evaluating the implications of transportation infrastructure investment is clearly dependent upon precise economic objectives being pursued. While goals such as growth and economic welfare are often complementary, they can have distinctly different implications when evaluating projects. For example, if economic growth is valued for its own sake, a lower weight will be attributed to social and environmental impacts. The method chosen for choosing the level and character of transportation infrastructure investment must be consistent with the chosen public objectives.

PLAN OF THE CHAPTER

This Chapter provides a taxonomy of methodologies in relation to the alternative objectives of transportation infrastructure investment and provides specific guidelines on the emerging "top-down" versus "bottom-up" methodological debate. As in Chapter 2, this analysis will be expanded in Part II and provide a foundation for guidelines in the Primer.

A TAXONOMY OF METHODOLOGIES

The analysis reported in Table 2 identifies the inventory of methodologies and indicates how alternative applications relate to specific investment selection criteria and investment objectives. The Table is presented in the Primer as a "roadmap" to steer decision-makers and practitioners to the correct methodology, given the stated objectives of policy.

The Table indicates that all methodological applications fall into one of three broad classes, as follows;

- o Social Benefit-Cost Analysis;
  - – with partial equilibrium-determined impacts.
  - – with general equilibrium-determined impacts.
- o Financial Benefit-Cost Analysis;
- o Macroeconomic Analysis; and
  - – with partial equilibrium-determined impacts.
  - – with general equilibrium-determined impacts.

The distinction between "partial equilibrium" and "general equilibrium" impacts refers principally to the identification of productivity and other economic benefits of transportation investments in all markets. Chapter 4 is devoted entirely to this problem, out of which a precise definition of general equilibrium impacts emerges. This in turn provides the basis for simplifying the language of general equilibrium that is used in the Primer.

As shown in Table 2, the generic methodologies each cover a range of possible applications. Social Benefit-Cost Analysis can be applied with or without certain features, the choice determining which selection criteria and thus which economic objective is actually being measured. Macroeconomic methodologies include various forms of Impact Analysis, again the choice determining the objective being measured. Macroeconomic models also include a class of applications that have been known as "top-down" approaches in the recent public debate. In measuring econometrically the impact of transportation investment on aggregate employment and productivity levels, these applications help establish the aggregate impact of public investment on the two key components of economic growth.

Our preliminary evaluation finds substantial evidence of mis-matches between methodology and stated objectives. Decision-makers and practitioners will thus need clear guidance from the Primer in order to make reasoned methodological choices.

The major conclusions from Table 2 may be summarized as follows:

1. Only Social Benefit-Cost Analysis addresses both productivity and economic welfare objectives;

2. Only Social Benefit-Cost Analysis applied in a general equilibrium framework addresses the productivity objective comprehensively;

3. Economic Impact Analysis without tests of incrementality-tests of whether income and employment impacts represent net increases versus re-distributed economic activity -- measures the achievement of distributional objectives (income, regional or sectoral). This methodology signals nothing about the productivity, growth, or welfare and efficiency implications of investment;

4. Economic Impact Analysis with tests of incrementality measure transportation infrastructure's contribution to productivity and growth objectives. This approach signals nothing about the economic welfare and efficiency implications of investment; and

5. Econometric ("top-down") methodologies that measure the impact of aggregate transportation investment on aggregate employment and productivity levels do not address the welfare objective. Thus aggregate productivity-infrastructure equations can indicate that higher levels of public investment would yield higher private sector productivity and growth; they cannot signal the level or mix of increased spending that would maximize welfare and thus optimize transportation's economic contribution.

We can conclude from the above that some methodologies and applications are insensitive to certain goals while being sensitive to others. A general example is the difference between **Economic Impact Studies** and **Benefit-Cost Studies.** Our preliminary evaluation indicates that economic impact studies usually measure the gross number of jobs affected by a proposed public investment. The numbers generated by these studies are often misrepresented as jobs "created". In fact, many of the jobs may be transferred from other sectors or regions. If national welfare is the goal, a **Benefit-Cost Analysis** study will be more appropriate, since it will distinguish between net gains and gross transfers. Only where the size of regional or sectoral transfers is the goal will **Economic Impact Studies** provide sufficient information.

TABLE 2: ALTERNATIVE EVALUATION METHODOLOGIES AND THEIR RELATED ECONOMIC OBJECTIVES OF TRANSPORTATION INFRASTRUCTURE INVESTMENT

METHODOLOGY	APPLICATION	SELECTION CRITERIA	OBJECTIVE
	Economic Cost-Benefit Analysis incorporating national allocative benefits and costs; excluding non-production externalities and employment/leisure choices:	Internal Rate of Return greater than private Internal Rate of Return	National Productivity. Increase the value of total national output per capita through efficient use of factor inputs (capital)
		Internal Rate of Return greater than zero	National Growth. Increase the value of total national output through efficient use of factor inputs and/or increased employment of factor inputs
	With income distribution preferences reflected through shadow prices and distributional weights.	Net Present Value	National Income Distribution. Redistribute national income in favor of sectors (private, public, targetted industries) and/or sub-national regions (communities, states, development zones)
SOCIAL COST-BENEFIT ANALYSIS	Cost-Effectiveness/Least-Cost Analysis	Cost-Effectiveness Ratios	Transportation Infrastructure Productivity. Output of transportation services relative to direct cost of achieving the output.
Partial Equilibrium Models. CBA models without general equilibrium determined shadow prices.	Economic Cost-Benefit Analysis incorporating general equilibrium determined shadow prices and national allocative benefits and costs; including externalities and employment/leisure choices:	Net Present Value	National Welfare. Increase national welfare where welfare is dependent upon national income (the value of national output), external factors (environmental quality) and leisure time.
General Equilibrium Models. CBA models with general equilibrium determined shadow prices.	With income distribution preferences reflected through shadow prices and distributional weights.	Net Present Value	National Distribution/National Welfare. Increase national welfare, where welfare includes income associated with specific activities, sectors and/or sub-national regions.
	Economic Cost-Benefit Analysis incorporating regional allocative benefits and costs; excluding externalities and employment/leisure choices:	Internal Rate of Return greater than private Internal Rate of Return	Regional Productivity (National Income Distribution). Increase the value of total regional output per capita through efficient use of factor inputs (capital)
	With income distribution preferences reflected through shadow prices and distributional weights.	Internal Rate of Return greater than zero	Regional Growth. (National Income Distribution). Increase the value of total regional output through efficient use of factor inputs and/or increase employment of factor inputs.
		Net Present Value	Regional Income Distribution. (National Income Distribution). Redistribute regional income in favor of specific sectors and/or sub-national regions.
	Economic Cost-Benefit Analysis incorporating general equilibrium determined shadow prices and regional allocative benefits and costs; including externalities and employment/leisure choices.	Net Present Value	Regional Welfare. (National Income Distribution). Increase regional welfare, where welfare is dependent upon regional income, external factors and leisure time.
	With income distribution preferences reflected through shadow prices and distributional weights.	Net Present Value	Regional Income Distribution/Regional Welfare (National Income Distribution). Increase regional welfare, where welfare includes income associated with specific activities, sectors and/or sub-regional areas.
FINANCIAL COST-BENEFIT ANALYSIS	Cost-Benefit Analysis incorporating financial benefits and costs valued at market prices.	Net Present Value	National Income Distribution. Redistribute national income in favor of specific sectors (private, public, targetted industries) and/or sub-national regions (communities, states, development zones)
		Cost Effectiveness Ratio	National Productivity. Increase the value of total national output per capita through efficient use of factor inputs (capital)

TABLE 2 (CONTINUED)

METHODOLOGY	APPLICATION	SELECTION CRITERIA	OBJECTIVE
MACROECONOMIC MODELS Partial Equilibrium Models. Bounded Econometric Models and Fixed Coefficient Input-Output Models General Equilibrium Models. Comprehensive Econometric Models and Variable Coefficient Input-Output Models. Econometric Models of Employment and Productivitiy Impacts	Economic Impact Analysis incorporating changes in components of national income/expenditure; excluding incrementality tests.	Change in Gross National or Regional Income/Expenditure/ Employment	National Income (or Sectoral and Regional) Distribution. Redistribute national income in favor of specific sectors (private, public, targetted industries) and/or sub-national regions (communities, states, development zones)
	Economic Impact Analysis incorporating changes in components of national income/expenditure; including incrementality tests.	Change in Gross National or Regional Income/Expenditure Change in Gross National or Regional Income/Expenditure per Capita	National Growth. Increase the value of total national output through efficient use of factor inputs and/or increased employment of factor inputs. National Productivity. Increase the value of total national output per capita through efficient use of factor inputs (capital)
	Economic Impact Analysis incorporating changes in components of regional income/expenditure; excluding incrementality tests.	Change in Gross Regional Income/Expenditure/ Employment	Regional Income (or Sectoral and Regional) Distribution Redistribute regional income in favor of specific sectors and/or sub-national regions
	Economic Impact Analysis incorporating changes in components of regional income/expenditure; including incrementality tests. General Equilibrium Land-Use/ Transportation Models	Change in Gross Regional Income/Expenditure Change in Gross Regional Income/Expenditure per Capita	Regional Growth. (National Income Distribution). Increase the value of total regional output through efficient use of factor inputs and/or increase employment of factor inputs. Regional Productivity (National Income Distribution). Increase the value of total regional output per capita through efficient use of factor inputs (capital)
	Aggregate Econometric Analysis of private productivity change in response to private and public sector fixed capital formation.	Change in Private Sector Productivity in Response to Change in Aggregate Level of Transportation Infrastructure Investment	National or Regional Productivity. Increase in aggregate productivity in response to private and public investment.
	Aggregate Econometric Analysis of Employment Level in Response to Public Fixed Capital Formation	Employment in the Transporation Sector	Increased Employment in the Transportation Sector.

THE TOP-DOWN BOTTOM-UP DEBATE IN THE CONTEXT OF METHODOLOGICAL CHOICE

On-going debate over whether total public investment is below desirable levels stems in part from macro-econometric indications that the marginal productivity of public investment at present exceeds that of private investment. This implies that there is relatively too little public investment taking place, since dollars invested in public infrastructure are estimated to earn a higher return than in the private sector.

Coupled with this debate is the question of whether evaluating public investments on a project by project basis leads to under-investment from the perspective of the total economy. Does "bottom-up" project by project evaluation yield lower investment than the level implied in a "top down" assessment of the overall economy?

Is Properly Done Benefit-Cost Analysis Enough?

It has been stated that:

> "Properly done Benefit-Cost Analysis for each project should result in the best aggregate level of investment for the whole economy. Therefore any divergence between a top-down approach and a bottom-up approach to determining a nation's investment can only result from errors in application."

This statement is true if:

- The primary objective is to maximize national welfare; and
- All benefits and costs (general equilibrium benefits and costs) are accounted for.

(Validation of the statement also requires that funding is forthcoming for all projects that pass the welfare (net present value) test. As discussed in Chapter 5, under-funding rather than methodological problems represents one possible source of any under-investment.)

The primary objective is welfare maximization. If economic growth is valued over and above its impact on national or regional economic welfare, Benefit-Cost Analysis, even with full accounting for general equilibrium impacts, will underestimate the desired aggregate level of investment. If growth is the primary objective, top-down methodologies would be more likely to yield the "correct" level of investment (although the best mix of investments would require rate of return analysis for individual projects). Chapter 2 finds, however, that growth for its own sake is inadequate as the objective of transportation infrastructure investment and that the productivity and growth forthcoming from the welfare maximizing level and mix of transportation investments is consistent with U.S. economic objectives.

It is not clear whether Benefit-Cost Analysis accounts for general equilibrium impacts. In an earlier paper prepared under the 2020 process, the authors argue that higher-than-forecast rates of economic growth are necessary to sustain U.S. competitiveness and living standards and that the nation's transportation infrastructure has an important role to play in that process. In the same Part, the authors argue that the key to achieving the higher rate of growth lies in the nation's productivity and that capital formation-both public and private-is the major source of productivity increases in the United States. This argument rests upon a complementary relationship between public capital formation and private sector productivity, whereby improved transportation facilitates the adoption of more efficient production technology and processes in private industry ("just-in-time" inventory systems, for example).

With its emphasis on time savings and savings in user costs, however, questions arise about the ability of Benefit-Cost Analysis, whether in theory or in practice, to recognize the complete and general (hence, "general equilibrium") implications of transportation investments. This is the subject of the following Chapter.

CHAPTER 4

ARE GENERAL EQUILIBRIUM IMPACTS MEASURED IN BENEFIT-COST ANALYSIS?

Our starting hypothesis is that project by project appraisal, using Benefit-Cost Analysis and related techniques, will, if properly applied, lead to the correct (i.e. welfare maximizing) mix and level of investment. The Primer deals with the correct application of the framework, including selecting options, identifying benefits and costs, quantifying benefits and costs, use of discounting, the proper criterion (i.e. NPV) and so on.

As well, however, we examine a second, hypothesis-that the Benefit-Cost Analysis framework fails to capture the "general equilibrium" impacts of projects. These include improvements in private sector productivity stemming from better public infrastructure (i.e. the ability to adopt just-in-time inventory management) agglomeration economies and so on. Aschauer argues that public infrastructure has positive direct and indirect effects on private sector output and productivity growth. Quoting liberally from Aschauer, the direct effect on private sector output growth arises from the availability of public capital to support private sector production (facilitating distribution, etc.). The indirect effect evolves from the complementarity between private and public capital in private-sector productive activity; an increase in the stock of public capital raises the return to private capital which, in turn, serves to spur the rate of expansion of the private-sector capital stock.

Our second hypothesis thus states that the spur to labor productivity and growth is not fully captured in Benefit-Cost Analysis studies, either because of limitations in the theoretical framework or because of limitations in benefit estimation methodologies. The growing suspicion among transportation policy makers and engineers is that either one or both is indeed the case; and that as a result even the most proficient use of Benefit-Cost Analysis creates the risk that "the sum of all infrastructure decisions taken according to strict rules of net present value maximization will fail to achieve the level and mix of transportation investments that maximize productivity, national economic growth and welfare maximization" (Hickling Proposal to NCHRP, p. 9).

The omission of general equilibrium benefits can occur for one of the following two reasons:

- **Faulty Theoretical Framework**--the possibility that the underlying principles of Benefit-Cost Analysis in application to public projects are such that we ignore certain general equilibrium impacts such as induced gains in private sector productivity, agglomeration benefits and so on; and

- **Limited Methodologies**--the possibility that methodologies are not available to measure impacts that go beyond conventionally measured user benefits, costs and externalities, even if the principles of Benefit-Cost Analysis are properly and accurately applied.

It is also possible, of course, that most conventional applications of Benefit-Cost Analysis in transportation projects, focusing on time-saving-related user benefits and external costs such as noise, air pollution and so on, do reasonably approximate total benefits and costs.

PLAN OF THE CHAPTER

This Chapter poses the following two questions;

- What, generically, are the categories of general equilibrium impacts that are at risk of omission in conventional Benefit-Cost Analysis and conventional applications of Benefit-Cost Analysis?

- Can the theoretical basis for Benefit-Cost Analysis be shown to account for all prospective impacts of transportation investment on productivity and other general equilibrium impacts? (Only if this is the case can it be said that the sum of all infrastructure investments made according to strict rules of net present value maximization provide the most desirable level and mix of investments from an aggregate economic point of view.)

From our review of the economic literature, we have determined that a complete theoretical proof is required before Benefit-Cost Analysis can be put forward as the most appropriate means of gauging the correct level and mix of transportation infrastructure investment. This is principally because the theoretical soundness of Benefit-Cost Analysis from the viewpoint of the general equilibrium impacts of public infrastructure (particularly its impact on private productivity) has not been rigorously determined in the literature. Such a proof is not required for the Primer itself. But if such a proof is possible, the Primer can support the use of Benefit-Cost Analysis and provide any special corrections that the theoretical exercise suggests; it can also provide practical guidance to decision-makers and practitioners in application.

In addition, the Chapter provides the basis for establishing:

- The quantitative importance of general equilibrium benefits in the estimated net present value of projects;

- The circumstances under which general equilibrium benefits are most likely to be a significant outcome of transportation investment (i.e. large scale additions to the infrastructure; repair and maintenance projects; particular modes and so on); and

- A framework for developing the methodologies required to incorporate general equilibrium impacts into the conventional economic evaluation of transportation investment analysis.

With a sound basis for answering the three questions posed above, Part II of the project will complete the analysis and Part III contains the results that are incorporated into the Primer.

A TAXONOMY OF GENERAL EQUILIBRIUM IMPACTS

The conventionally measured benefits and costs of transportation infrastructure investment are well understood in the literature. Benefits include gains to users of the transportation system in the form of cost and time savings while costs include capital expenses, incremental operating and maintenance costs and "external costs" such as noise, air pollution and so on.

It is conventionally assumed that the value of user-benefits incorporates the total value of productivity and output gains that occur throughout the economy as a result of investment. For example, a highway project will improve travel times for workers and reduce operating costs for trucking. To the extent that such benefits are passed along to industry, they permit greater output for a given call on labor and transportation resources. Depending upon the strength of market forces in the industries in question, final consumers would gain from lower prices.

While the kind of interactions outlined above will capture economy-wide impacts under certain circumstances, there may be conditions under which further impacts would occur and the question must be raised whether the conventional yardstick of "user-benefit" captures such effects. Such impacts include fundamental technological changes in industry that transportation infrastructure improvements permit and which bring about structurally improved productivity. For convenience, we call such effects general equilibrium impacts; as we progress, however, terms are developed that make the concepts broadly accessible.

In order to examine the question rigorously, we have developed a taxonomy of general equilibrium impacts that is believed to be comprehensive. The taxonomy is as follows:

1. **Technical Change**. New technologies change the production possibilities of an economy and shift the demands for factor inputs. Many of these technology changes make older vintages of capital obsolete and increase the value of new vintages of capital.

    - Technological change directly affecting public infrastructure (FAA National Airspace System Plan);

    - Technological change in transportation sector increasing demand for public infrastructure (airline hubs);

    - Technological change in transportation sector reducing demand for public infrastructure;

    - Technological change in other sectors increasing demand for public infrastructure (just-in-time inventory); and

    - Technological change in other sectors reducing demand for public infrastructure (telecommunications).

2. **Returns to Scale**. Nonconstant returns to scale increase or decrease the unit value of public infrastructure investment. Returns to scale may be direct (pertaining to operating cost of public infrastructure) or indirect (pertaining to the general economic activity supported by the infrastructure). Current valuation methods may not capture the change in unit valuations occurring where large infrastructure investments take place.

    - Direct increasing returns to scale;

    - Direct decreasing returns to scale;

- Indirect increasing returns to scale (agglomeration effects); and
- Indirect decreasing returns to scale (urban congestion).

3. **Better Utilization of Excess Capacity**. Within certain locales, some private factors of production may be under-utilized. This may take the form of structural unemployment or excess capacity. It may occur within the transportation sector or in other sectors of the economy.

    - Capacity utilization in transportation; and
    - Capacity utilization in other sectors (multiplier impacts).

4. **Price Effects**. Prices for final goods and services as well as prices for variable factor inputs are determined by competitive forces exogenous to the economy being considered. Changes in prices will shift the demand curve for public infrastructure. In addition, price distortions may have an impact on the welfare measures.

    - Price effects within transportation sector; and
    - Indirect price effects.

5. **Project Complementarity and Substitutability**. Two (or more) infrastructure projects may be complements. The construction of the first may lead to an upward shift in the demand curve for the second. Projects may also be substitutes, in which case the construction of the first will lead to a reduction in demand for the second. Often projects may be of the same or different modes.

    - Intramodal project complementarity;
    - Intramodal project substitutability;
    - Intermodal project complementarity; and
    - Intermodal project substitutability.

GENERAL EQUILIBRIUM IMPACTS AND THE VALIDITY OF BENEFIT-COST ANALYSIS

In this section we address the question of whether the general equilibrium impacts outlined in the taxonomy above are captured by conventional Benefit-Cost Analysis measures. We begin by developing a general equilibrium model and deriving the Benefit-Cost Analysis rules from it. Next, we consider each of the general equilibrium impacts in 1, namely:

- Technical Change;
- Returns to Scale;
- Capacity Utilization;

- Price Effects; and
- Project Substitutability and Complementarity.

We also discuss how they change the general equilibrium model and the Benefit-Cost Analysis rules, if at all. We then proceed to show how these impacts influence the valuation of shadow prices, giving examples related to the transportation industry.

In order to demonstrate the Benefit-Cost Analysis rules in general equilibrium, we generalize Boadway's (1975) model. The Boadway model considers a single consumer, a private sector, and a public sector. His model does not include any public goods. We generalize the Boadway model by explicitly considering public infrastructure as a public good and by differentiating two industries in the private sector--one that uses public infrastructure and one that does not. The consumer also uses the public infrastructure.

We start by specifying the consumer's utility function:

$$u(x, l) \tag{1}$$

where x is a vector of traded goods and l is public infrastructure. An element of x is positive if the consumer is a net purchaser of the good and negative if the consumer is a net supplier of the good (e.g. labor supply). The consumer is subject to the budget constraint

$$qx = m \tag{2}$$

where q is the vector of after tax prices of x while m is a lump sum transfer to the consumer. (If m is negative, it is a lump sum tax.) Maximizing (1) subject to (2) yields net demand functions of the form

$$x = x(q, l, m) \tag{3}$$

The first private industry does not use public infrastructure while the second has infrastructure b. The two industry production functions are given by:

$$f_1(y_1, 0) = 0$$

$$f_2(y_2, b) = 0 \tag{4}$$

where y_1 and y_2 are net output vectors of the traded goods. The vectors take on positive values if the good is an output, and negative values if the good is an input to the industry. The public sector produces net output vector z and public infrastructure k. The public sector's production function is given by:

$$g(z, k) = 0 \tag{5}$$

All sectors face the same before tax price vector p for their traded goods. The price vectors have the relationship

$$q = p + t \tag{6}$$

where t is the vector of taxes. Market clearing equations are:

$$x = y_1 + y_2 + z$$

$$l = b + k \tag{7}$$

Profit maximization in both private sectors yield the net supply functions:

$$y_1 = y_1(p, 0)$$

$$y_2 = y_2(p, b) \tag{8}$$

Measurement of Welfare Change. To find the welfare change from any government activity we first totally differentiate the consumer's utility function (1).

$$du = (\partial u/\partial x) \cdot dx + (\partial u/\partial l) \cdot dl$$

$$dW = q \cdot dx + v \cdot dl \tag{9}$$

where dW is the monetary welfare measure and v is the shadow price of l. Since $dx = dy_1 + dy_2 + dz$, and using the price identity (6) we have

$$dW = (p + t) \cdot (dy_1 + dy_2 + dz) + v \cdot dl \tag{10}$$

Totally differentiating the production functions (4) and assuming profit maximization we have:

$$(\partial f_1/\partial y_1) \cdot dy_1 + (\partial f_2/\partial y_2) \cdot dy_2 + (\partial f_2/\partial b) \cdot db = 0$$

$$p \cdot (dy_1 + dy_2) + s \cdot db = 0 \tag{11}$$

where s is the shadow price of b for sector 2. Substituting (11) into (10) we have

$$dW = (q - p) \cdot dx + p \cdot dz - s \cdot db + v \cdot dl$$

$$= t \cdot dx + p \cdot dz - s \cdot db + v \cdot dl \tag{12}$$

The change in welfare is equal to the change in traded goods times the difference in marginal value between the consumer and producer sectors, plus net income in the government sector, plus the net shadow value increase to both the producer and consumer sectors from the infrastructure investment. The government budget constraint is obtained by combining equations (2), (6), and (7)

$$(p + t)(y_1 + y_2 + z) = m$$

$$t \cdot x + p \cdot y + p \cdot z = m \tag{13}$$

To simplify the analysis we assume that t is set to zero and any government net income shortfall is met by a lump sum tax. Then

$$dW = p \cdot dz - s \cdot db + v \cdot d\mathit{l} \qquad (14)$$

Efficient government production implies that

$$(\partial g/\partial z) \cdot dz + (\partial g/\partial k) \cdot dk = 0$$

$$p \cdot dz + w \cdot dk = 0 \qquad (15)$$

where w is the shadow price of producing k in the public sector. Combining (14) and (15), and recognizing that $dk = d\mathit{l} - db$, we have

$$dW = (v - w) \cdot d\mathit{l} - (s - w) \cdot db \qquad (16)$$

The change in welfare for any incremental increase in public infrastructure is equal to the user's shadow price less the government sector's shadow price for supplying the infrastructure.

We now turn to the "general equilibrium impacts." Technical change is introduced to the model either by allowing the production functions to be time dependent (if the technical change is disembodied) or by distinguishing different vintages of capital as different goods in the model (if the technical change is embodied). In the disembodied technical change model, equilibrium prices and quantities will vary by period. The shadow prices of public infrastructure, which are a function of market prices, will also change by period. Benefit-Cost Analysis rules will capture welfare gains in a multi-period model as long as one accounts for the changes in shadow prices.

The embodied technical change model focuses on different vintages of capital. In the early periods of the multi-period model the newer vintage capital is unavailable and market equilibria are established without it. This yields an initial set of shadow prices for public infrastructure. After the newer vintage capital is made available, new market equilibria are established yielding new shadow prices. If the new capital appears in the form of public infrastructure, shadow prices are established for both the older vintage and newer vintage public infrastructure. Once again the Benefit-Cost Analysis rules will capture welfare changes as long as it captures the changes in shadow prices. This holds true regardless of whether the technical change occurs in either of the private industries, or in the public sector.

Since the model does not restrict any of the sectors to constant returns to scale, the Benefit-Cost Analysis rules hold regardless of whether there are increasing returns to scale or decreasing returns to scale. For example, increasing returns to scale occur in the second industry if

$$f_2(\lambda y_2, \lambda b) < 0 \qquad (17)$$

while decreasing returns to scale occur if

$$f_2 (\lambda y_2, \lambda b) > 0 \qquad (18)$$

Only the first industry is restricted to non-increasing returns to scale, in order that a profit maximizing optimum exists for that industry. If industry one were generalized to use public infrastructure, or if it were to have quasi-fixed inputs, this condition could also be relaxed.

The model can be extended in a straightforward manner to include quasi-fixed inputs in any of the sectors. These quasi-fixed inputs would formally appear in the same manner as the infrastructure variables. The shadow prices of the infrastructure are influenced by levels of the quasi-fixed inputs, but the Benefit-Cost Analysis rules do not deviate from the measurement of the shadow prices in order to account for welfare changes. Consequently, it would be inappropriate to augment shadow price valuations with measures of capacity utilization change in other sectors.

As mentioned above, the prices of traded goods do affect the shadow prices for public infrastructure. Consumers fit their consumption patterns and firms their production patterns to relative prices. This in turn determines the shadow prices. Furthermore, if it is not feasible to use lump sum taxes to finance public infrastructure, equation (12) shows that "welfare triangles" throughout the economy will change as the economic activity changes.[1]

If k is multidimensional, the shadow price of one mode can clearly be a function of the other's level. If two types of infrastructure are complements, then the shadow price of one increases with the level of the other. If they are substitutes, the shadow price falls as the level of the other increases.

Because the Boadway model deals with incremental changes, it does not have a feedback effect on equilibrium market prices. For non-incremental changes Boadway notes that the welfare change is a line integral of the incremental changes. The welfare changes can be directly calculated by stipulating the general equilibrium model and solving for the equilibrium before and after the infrastructure investment. However such an approach requires a great deal of information and effort. Fortunately, Hammond (1980) has shown that in most cases, it is not necessary to explicitly consider the feedbacks on market prices when evaluating non-incremental investments. Using existing prices to measure welfare change generally leads to an iterative planning procedure that satisfies Malinvaud's (1967) criteria of eventually leading to an optimum, of being feasible at each step, and of improving welfare at each step.

Benefit-Cost Analysis rules, if implemented correctly, provide a sufficient basis for evaluating public infrastructure investment. This is true even when such factors as technical change, returns to scale, capacity utilization, price effects, and project complementarity and substitutability occur. In all cases, shadow prices for infrastructure provide the basis for measuring welfare change. The actual shadow prices are dependent on economic conditions. In the next section, we illustrate some of these dependencies.

MEASUREMENT OF SHADOW PRICE

Equations (9) and (11) link shadow prices of public infrastructure to the cost of maintaining customer utility and the cost of production respectively. The previous section focused on the utility function and production function in deriving the welfare results. Diewert (1974) has shown that the preferences and

[1] Other institutional and legal factors, e.g. minimum wage laws, also introduce efficiency losses through the economy. These will change as the economy changes.

technology implicit in the utility and production functions can be equivalently represented by expenditure functions and variable profit functions. Furthermore these functions directly lead to the shadow prices of infrastructure, showing how they relate to other economic variables.

The expenditure function is obtained by minimizing expenditure, conditional on utility and market prices. The expenditure function that is dual to equation (1) can be represented by the function

$$e = e\,(q, l, u) \tag{19}$$

Differentiating e with respect to q yields the compensated demand equations while differentiation with respect to *l* represent the (compensated) shadow price of infrastructure. Thus the shadow price v is a function of market prices q, the level of infrastructure *l*, and the utility level u.

$$v = v(q, l, u) \tag{20}$$

Similarly, the variable profit function for industry two is obtained by maximizing profits subject to (4). Variable profits are the difference between revenues and payments to variable inputs, and it is a function of variable input prices, quasi-fixed inputs, and public infrastructure. The variable profit function corresponding to (4) can be represented by the function

$$\pi_2 = \pi_2(p, b) \tag{21}$$

Differentiation with respect to b yields the shadow price of public infrastructure for industry 2. This shadow price is a function of market prices and the level of infrastructure.

$$s = s(p, b) \tag{22}$$

The actual shadow price can be influenced by various factors including the various "general equilibrium" impacts mentioned above. We analyze each of these impacts in turn, focusing on how the impacts change the shadow price for the producer. Some of the impacts will also pertain to the consumer sector. In these cases the impact on equation (20) will exactly parallel the impact on equation (22).

TECHNICAL CHANGE

As mentioned previously, technical change can occur in the public sector, private industries using infrastructure, or private industries not using infrastructure. The most useful case to consider for public sector technical change in embodied technical change. In equation (21) we distinguish b_1 from b_2, each of which represents a different technology. Before technical change occurs, only b_1 is available. With the existing level of $\hat{b}_1$, the shadow price of b_1 is

$$s_1 = s_1(p, \hat{b}_1, 0)$$

$$= \partial\pi(p, \hat{b}_1, 0)/\partial b_1 \tag{23}$$

After the new technology is available the shadow price for b_2 becomes relevant.

$$s_2 = s_2(p, \hat{b}_1, 0)$$

$$= \partial\pi(p, \hat{b}_1, 0)/\partial b_2 \quad (23)$$

Because the new technology is an improvement over the old, $s_2 > s_1$. Graphically one can think of the demand for b_2 lying above b_1, as shown in Figure 1. D1 represents the shadow price curve for the old technology. As capacity expands from b to b using the old technology, the area A represents the increased savings that the firm can realize due to the greater availability of public infrastructure. However with the new technology even greater savings are available which is reflected in the higher shadow price curve D2. If the incremental capacity is in the form of the new technology, additional savings are available, represented by the area B.

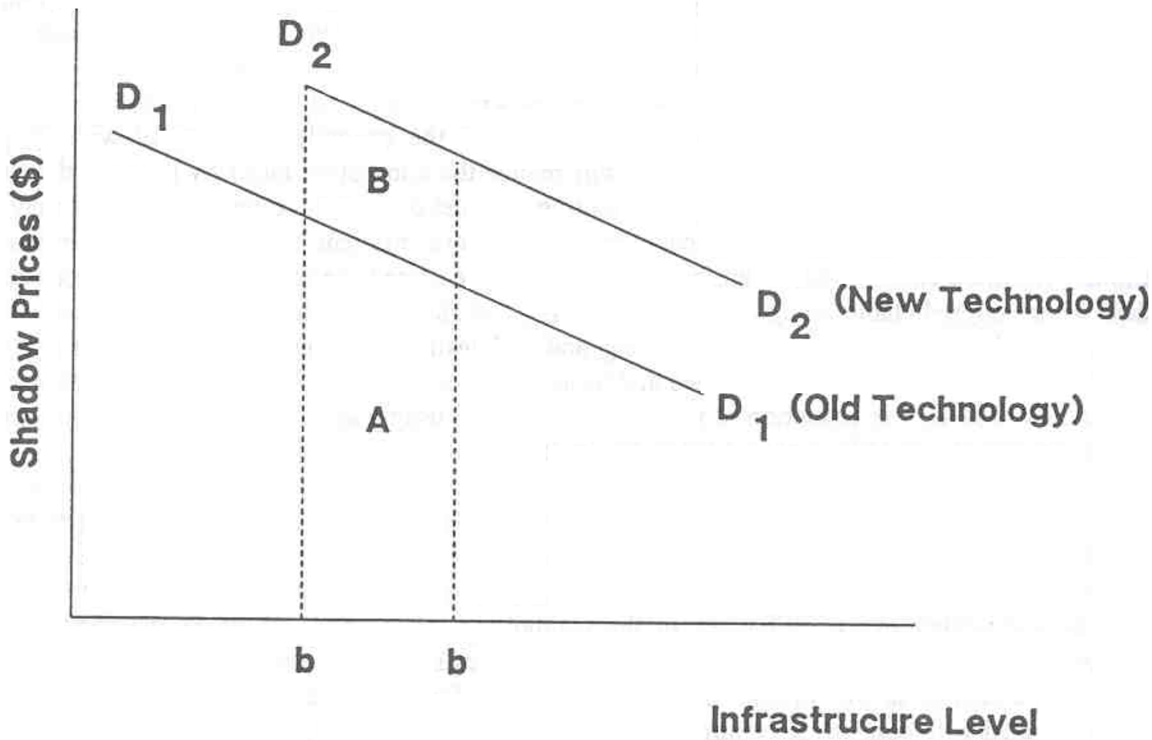
To think through how these savings might arise, consider the example of a tunnel with frequent congestion. The installation of a second tunnel will reduce the congestion faced by users of the tunnel for the trips they currently make, reducing their waiting and fuel costs at the tunnel. The users may also decide to also use the tunnel more frequently leading to more efficient trip routing and further cost reductions. All these costs are captured in the area A. At the same time there may be instances during the day when unpredictable congestion still occurs. A second technology is advanced which communicates when the congestion is occurring and automatically reroutes traffic. With this new technology, the congestion is further reduced and users are faced with less uncertainty when approaching the new tunnel. The further reduction in waiting time and fuel usage, and the induced utilization related to reduced uncertainty all reduce costs further by an amount B.

Technical change in the infrastructure using industry changes the production function which in turn changes the factor demand equations for inputs and the shadow price of infrastructure. This can be seen by modifying equation (21) to include an index of technology. The shadow price function (22) also includes the technology index. Changes in the technology index create shifts in the shadow price function, similar to that exhibited in Figure 1. In our tunnel example, suppose that a manufacturing firm is considering a change to just-in-time inventory methods. Before the change, waiting time and fuel expense associated with congestion capture the shadow price of the tunnel, and capacity expansion from b to b leads to a cost reduction of amount A. Going to just-in-time inventory methods increases the price of congestion due to the timing mismatches between deliveries and production that arise. This is reflected in the upward shift in the shadow price curve to D2. Capacity expansion now adds additional cost savings of B.

Finally technical change in other sectors of the economy can work either to increase or decrease the shadow price for an infrastructure using firm. Suppose that technical change elsewhere in the economy increases demand for our manufacturing firm's product, driving its price up. The costs of congestion suddenly increase, because the lost sales resulting from it now account for greater revenue. Consequently the shadow price of capacity increases (from D1 to D2 in Figure 1) and the value of capacity expansion increases. In Figure 2 we give examples for these various forms of technical change occurring in the highway, mass transit, and air modes of transportation.

Highway. In the highway mode, limited access and unlimited access highways represent different technologies. Cost savings to the firm due to highway capacity expansion might include less congestion, greater highway speeds, and greater safety. However the amount of savings can differ markedly

FIGURE 1



Shadow Price of Capacity Expansion with Old and New Technologies

FIGURE 2

Examples of General Equilibrium Effects

General Equilibrium Effect	Highway Transport	Mass Transit	Air Transport
Technical Change			
a. Embodied in Infrastructure	limited access vs. unlimited access highways	bus vs. fixed rail	FAA National Airspace System Plan
b. Transportation Using Industry	just-in-time inventory		just-in-time inventory
c. Elsewhere in Economy (communications)	fax technology leading to fewer courier services	decentralization of businesses, more telecommuting	telecommunications replacing travel
Returns to Scale			
a. Increasing Returns to Scale	agglomeration effects	agglomeration effects	agglomeration effects
b. Decreasing Returns to Scale	congestion effects	congestion effects	oversized airport facility
Utilization of Excess Capacity	increased general economic activity resulting from greater accessibility	increased accessibility of skilled labor force leading to increased economic activity	increased general economic activity resulting from greater accessibility
Price Effects	increased price for manufactured goods increasing demand for transportation	increased wage rates leading to increased demand for transit	increased price for manufactured goods increasing demand for transportation
Project Complementarity and Substitutability			
a. Complementarity	highway expansion with shopping center development	transit expansion with office park development	highway and airport expansion
b. Substitutability	mass transit and highways	mass transit and highways	airports in neighboring areas

depending upon whether additional capacity is in the form of limited access or unlimited access highways. In Figure 1, the shadow price of unlimited access highways would be represented by D1 and limited access highways by D2.

The just-in-time inventory process described above is an example of technical change occurring in a highway using firm that changes its shadow price for highway expansion. Finally, demand for a courier service may decline due to increased use of fax technology. The fax technology represents technical change occurring elsewhere in the economy, but affecting the shadow price for highway expansion. Since the price that the courier service can charge falls, the lost revenue due to congestion falls, leading to a downward shift in the shadow price.

Mass Transit. Mass transit is generally used by the consumer sector. Since one generally does not think of technical change occurring in the consumer sector, we do not present an example of household technical change affecting the demand for mass transit. However it is easy to think of examples for the other two instances of technical change. Fixed rail and bus represent alternative mass transit technologies. The two modes have different safety features, different speeds, and different comfort levels. These differences are reflected in different levels of "willingness to pay" that customers have for the different modes. These different "willingness to pay" values are the different shadow prices of the technologies.

Developments in telecommunications, allowing for decentralization of business and more tele-commuting, are examples of technical change that reduce the shadow price of mass transit capacity. In this example, the reduced shadow price results from reduced ridership, leading to fewer delays and more comfort on the trip. The added speed and comfort from capacity addition is now lower.

Air Transport. The FAA's National Airspace System Plan represents a new technology in air traffic control. This technology has the potential for overall cost reduction in many areas of the country, through facility consolidation. This is an interesting example, however, because in some areas the new technology would actually be more costly. Depending upon the location being considered, the shadow price of the new technology may be above or below the price of the old.

Just-in-time inventory methods can affect the shadow price of airport expansion. For firms shipping products by air, the value of reliability increases with the use of just-in-time. This translates into a higher shadow price for airport capacity, just as it did for highway capacity. Finally the telecommunications revolution can affect the shadow price of airport capacity as it might for highway and mass transit. As telecommunications technology is enhanced, the demand for air travel may decline. This would work to reduce congestion at existing airports, reducing the shadow price of capacity expansion.

RETURNS TO SCALE

Increasing returns to scale exist for the private sector if

$$\pi(p, \lambda b) > \lambda\pi(p, b) \qquad \lambda > 1 \qquad (25)$$

In such a case

$$s(p, \lambda b) > s(p, b) \qquad (26)$$

That is the shadow price increases as capacity expands. Figure 3 illustrates such an example. D1 represents the shadow price curve with constant returns to scale. Because the unit cost of production does not change as the scale of the operation increases, the unit shadow price remains constant as the size of the capacity addition increases. With increasing returns to scale, the unit costs of production declines as scale increases. Each incremental addition to capacity not only leads to the incremental profit from the additional unit sale, but by reducing the cost of all production makes an additional contribution to total profit. In Figure 3, the value to the firm of increasing capacity from b to b would be A if there were constant returns to scale but would be A + B with increasing returns to scale.

Decreasing returns to scale have the opposite effect on shadow prices. Decreasing returns to scale exist if

$$\pi(p, \lambda b) > \lambda\pi(p, b), \qquad \lambda > 1 \tag{27}$$

and

$$s(p, \lambda b) > s(p, b) \tag{28}$$

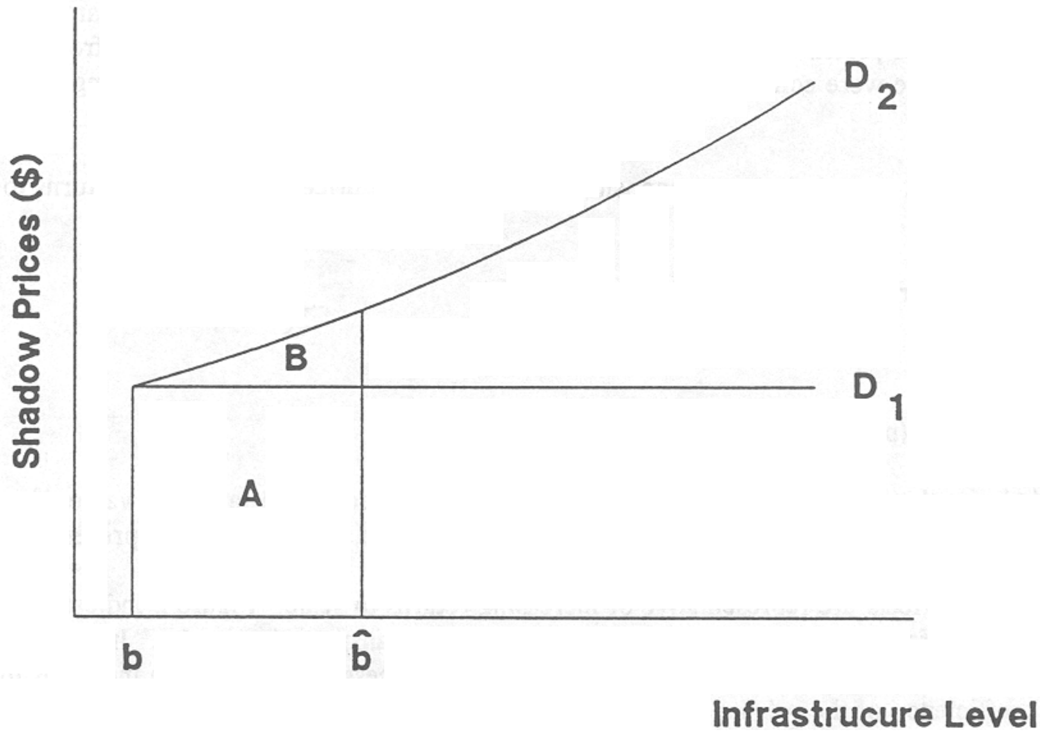
Figure 4 shows the impact of decreasing returns to scale. In such an instance the value of capacity expansion is less than it would be with constant returns to scale, by the amount represented by B.

Agglomeration effects are representative of increasing returns to scale. Figure 2 indicates that agglomeration effects can influence the shadow price of all transportation modes. In the economic development literature, it is generally recognized that the process or urbanization increases the economic efficiency of the private sector, reducing unit costs. Large scale infrastructure development may in such instances lead to larger unit cost reductions than small scale infrastructure development. Since the reduction in unit costs relates directly to the project's shadow price, this implies that the shadow price would not vary proportionately with the size of the project, but would increase more than proportionately.

One example might be the development of a planned community. The level of infrastructure chosen will dictate that community's size, which in turn will dictate the community's level of economic activity. Up to a certain point, the level of economic activity will rise more than proportionately with the infrastructure, due to scale effects. Scale will allow specialized activities to be profitable in the community. For both the smaller sized city and the larger sized city, the shadow price of infrastructure will relate to the incremental economic activity that additional infrastructure capacity will provide. The essential point, however, is that the shadow price will not be the same for the two communities. Since such urbanization would require various forms of transportation, agglomeration effects may be present for highway, mass transit, or air.

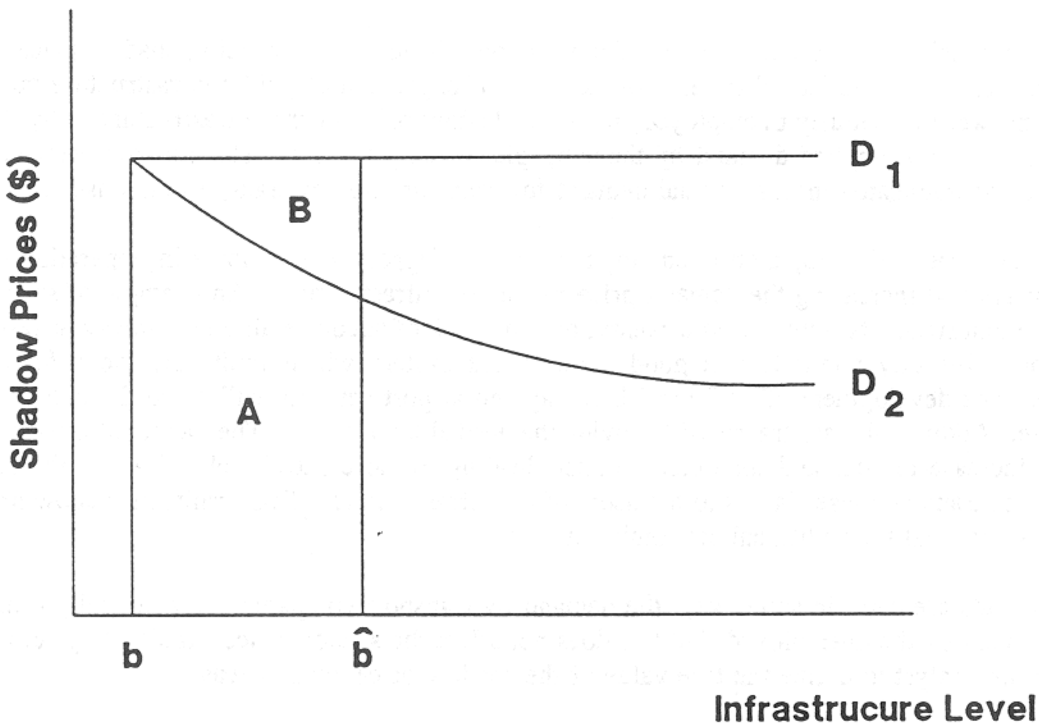
These agglomeration effects do not occur without limit, however. Once a community has surpassed its optimal size, additional infrastructure investment may simply lead to more congestion and private sector unit costs begin to rise. At this point, smaller infrastructure projects have the greater unit shadow prices. Manhattan might be an example of an area where congestion may be a factor. Large infrastructure projects may not be socially beneficial, inasmuch as they would create greater congestion.

FIGURE 3



Shadow Price of Capacity Expansion with Increasing Returns to Scale

FIGURE 4



Shadow Price of Capacity Expansion with Decreasing Returns to Scale

Geographic location can also be a factor in optimal infrastructure size. A community may be ideally located as a regional headquarters for corporations, but not ideally suited as a national headquarters. This would determine the optimal airport size for that community, and the unit shadow price of airport expansion would begin to fall as expansion beyond optimal size is being considered.

UTILIZATION OF EXCESS CAPACITY

As noted previously, even if some sectors of the economy have excess capacity, shadow prices provide the correct measure of welfare change. For example, if expansion of public infrastructure puts people to work who were previously unemployed, then the shadow price of the infrastructure is by definition higher, reflecting the implied demand by those people for employment. This implied demand may or may not be communicated through actual demand for transportation by transportation users.

If markets are free and fluid, then unemployment would depress wages, lowering operating costs for transport users and increasing the demand price for public infrastructure. An example of such impacts might be an industrial city with excess capacity, due to a lack of adequate air and highway infrastructure. Furthermore, this city might lack a good mass transit system which limits the labor force that is accessible. The development of additional highway and airport capacity will make the industries more competitive. Additional mass transit will provide the needed labor force. The increased activity in these firms will increase the demand for other products leading to more activity elsewhere in the economy. Market prices transmit these signals to the users of the infrastructure. This results in shadow prices that capture this potential for additional economic activity.

If labor markets are rigid in some way, the demand by transport companies may not fully transmit the implicit demand by the unemployed, but this does not affect the shadow price. It simply places a higher burden on the analyst to define the true value of the shadow price another way.

PRICE EFFECTS

The shadow price in equation (22) is a function of market prices as well as the level of infrastructure. Changes in market prices faced by the firm will affect the magnitude of the shadow price. If the price of the firm's output rises, the revenue from additional economic activity will increase. This in turn will increase the value of an additional unit of capacity. Similar changes in the firm's input prices will make additional infrastructure capacity either financially more attractive or less attractive.

Consider a manufacturing firm which faces occasional congestion in transporting its product by highway and air. This congestion will place some limit on the number of deliveries it can make in a day, with as well as leading to higher fuel and waiting costs. An increase in the price of its product, the congestion suddenly represents a larger amount of lost profits causing the shadow price of additional capacity to rise. An increase in the fuel price would increase the cost of waiting, once again increasing the shadow price of capacity. The changes in market prices can be thought of shifting the shadow price function in much the same way as technical change shifted the shadow price function in Figure 1.

Figure 2 shows output price changes as examples of price impacts for highway and air. For mass transit we list the impact of changing wage rates on shadow prices. Limited mass transit availability increases the travel time of a commute and limits the labor pool for a variety of firms. If wage rates rise in the community, the cost of the travel time increases for commuters. The shadow price of mass transit increases, reflecting the greater dollar savings from a given decrease in travel time.

PROJECT COMPLEMENTARITY AND SUBSTITUTABILITY

Since b and s were originally posted as vectors, it is interesting to consider the interrelationships between two elements in the vector. Rewrite equation (21) to distinguish two forms of public infrastructure, b_1 and b_2.

$$\pi(p, b_1, b_2) \tag{27}$$

Differentiation of the variable profit function yields the shadow prices for each form:

$$s_1 = \partial\pi/\partial b_1 = s_1\,(p, b_1, b_2)$$

$$s_2 = \partial\,\pi/\partial b_2 = s_2\,(p, b_1, b_2) \tag{28}$$

We can further differentiate the shadow price of b_1 to determine its relationship to b_2

$$\partial s_1/\partial b_2 = \partial^2\pi/\partial b_1\partial b_2 = \partial s_2/\partial b_1 \tag{29}$$

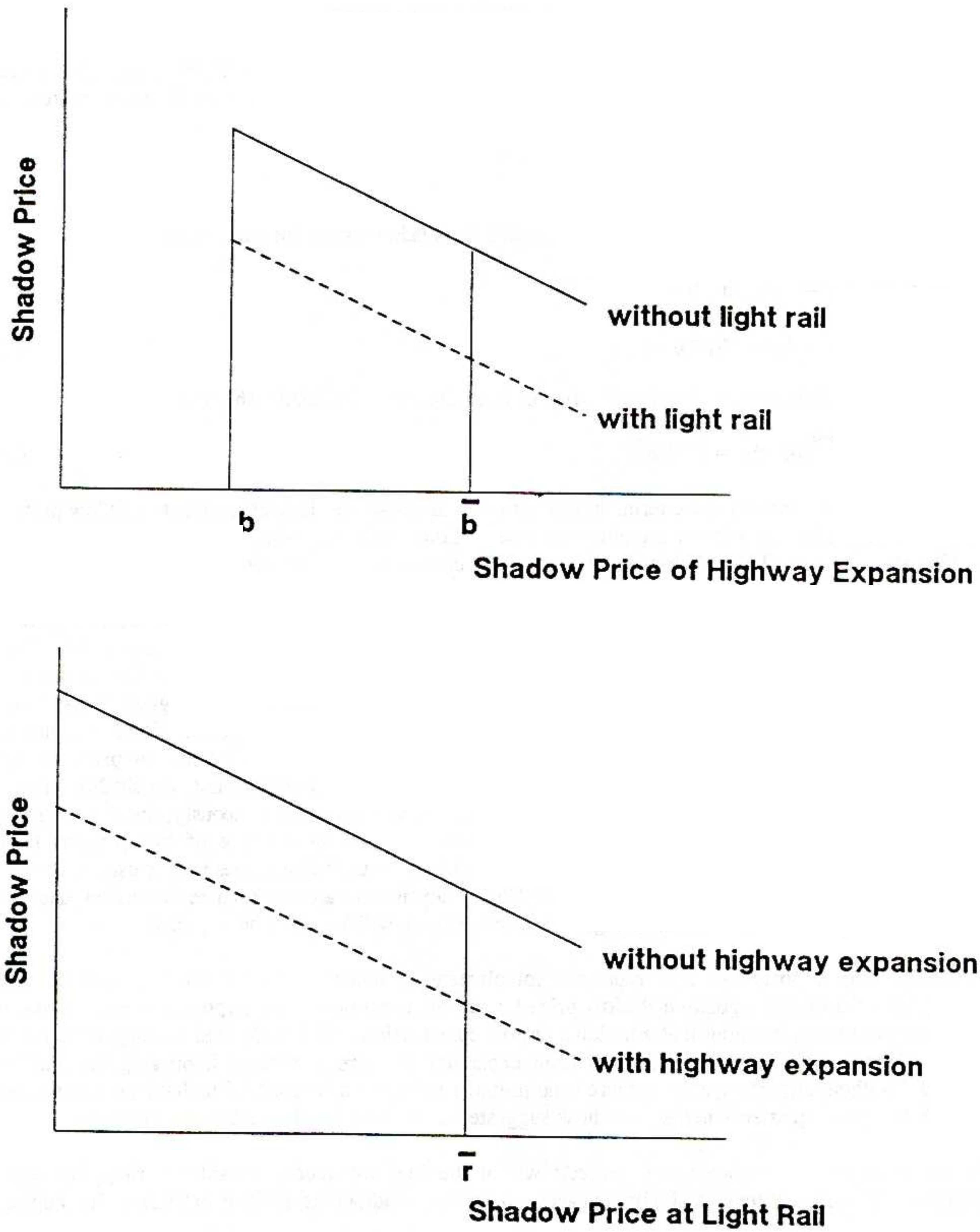
b_1 and b_2 are complements if the terms in equation (29) are positive. In such a case the shadow price of one increases as the capacity of the other increases. Conversely, b_1 and b_2 are substitutes if the terms in (29) are negative. This relationship also holds for consumers, as represented in equation (19).

To make this concept more clear consider the mass transit and highway example listed in Figure 2. Along a given corridor, the existing highway system leads to regular delays during rush hour. These delays translate into consumers' "willingness to pay" for additional highway capacity. This is shown in the first panel of Figure 5. These same consumers would also demonstrate a "willingness to pay" for a light rail transit system along the same corridor. This is shown in the second panel. However, once the additional highway construction is undertaken, the congestion is relieved and the shadow price for light rail will fall, as is shown in the figure. If the light rail system is undertaken first, the shadow price of additional highway capacity will fall. If both projects are undertaken simultaneously, the shadow prices for each mode are represented by the shifted curves. This is an example of two projects being substitutes. If project evaluation of each is done in isolation, the unshifted curves will be used to evaluate the projects. Assuming that both pass a Benefit-Cost Analysis test based on such an evaluation, and both are undertaken, the actual welfare changes from the projects will be less than expected.

Highways and airports can also represent complementary modes. An airport may face capacity constraints resulting in a positive shadow price for airport expansion. The airport, however, is served by a two-lane road, meaning that additional airport construction will quickly lead to congestion on the road. Consequently, the gains to users from expanding the airport without improving the road are limited. Without airport expansion, there is no pressure to improve the road. Simultaneous construction of both will yield greater benefits than those suggested by isolated studies of the two projects.

As an example of complementary projects within the highway mode, consider a shopping center development and the extension of a limited access highway. Without the highway extension, the shopping

FIGURE 5


Shadow Price
without light rail
with light rail
b
b̄
Shadow Price of Highway Expansion
Shadow Price
without highway expansion
with highway expansion
r̄
Shadow Price at Light Rail

center may create congestion and the benefits of the project may be limited. Without the shopping center, the highway development may provide excess capacity for the area's transportation needed. Project evaluation done in isolation may reject both projects. However, if the highway is constructed, the shadow price for the development shifts upward. If both are undertaken simultaneously, the higher shadow prices for each may create a net welfare increase. A similar relationship may hold between mass transit and an office park development.

Two airports in nearby locations may also constitute substitutes. Because of increased traffic, both airports may consider expansion. However if both airports are basing their analysis on the same incremental increase in traffic, both projects may be undertaken leading to excess capacity.

MEASURING GENERAL EQUILIBRIUM IMPACTS

The analysis thus far demonstrates that Benefit-Cost Analysis can, if properly applied, account for the full range of private sector productivity and other general equilibrium impacts. The analysis also provides the basis for answering the three key questions outlined at the start of this Chapter:

- The quantitative importance of general equilibrium benefits in the estimated net present value of projects;

- The circumstances under which general equilibrium benefits are most likely to be a significant outcome of transportation investment (i.e. large scale additions to the infrastructure, repair and maintenance projects, particular modes and so on); and

- A framework for developing the methodologies required to incorporate general equilibrium impacts into the conventional economic evaluation of transportation investment analysis.

The quantitative importance of general equilibrium benefits and the circumstances under which general equilibrium benefits are most likely to be a significant outcome of transportation investment can each be quantified by using the framework established in this Chapter. We propose to develop this analysis in Part II by mode, scale and type of project and region. This framework is also used in the Primer. The framework provides decision-makers and practitioners with guidance regarding the need to go beyond conventional measures of benefit in order to estimate benefits in the taxonomy of general equilibrium impacts identified earlier.

Measurement techniques for ascertaining the magnitude of general equilibrium impacts will also be addressed in Part II. The above analysis demonstrates that methodologies involve demand forecasting in relation to technical change and other industry impacts that are not conventionally measured. The analysis also indicates a possible role for "top-down" econometric studies from which "general equilibrium correction factors" could be developed for use by decision-makers and practitioners; this would mean that the detailed and complex analysis needed to establish the scope of general equilibrium impacts could be carried out centrally and the results provided for application by practitioners through the Primer (which would thus receive periodic up-dating).

In order to make the above model usable, a practical measurement framework for general equilibrium effects of infrastructure investment is presented and developed in Part II.

CONCLUSION

Questions have been raised regarding the adequacy of Benefit-Cost Analysis tests in evaluating public infrastructure projects. It has been conjectured that general equilibrium impacts, particularly those such as technical change, agglomeration effects, and capacity utilization, undermine Benefit-Cost Analysis sufficiently to call for its replacement in project evaluation. In this Chapter, we have developed a general equilibrium model to determine how welfare changes should be measured. We concluded that the theoretical foundation of Benefit-Cost Analysis, namely the evaluation of shadow prices for users of the infrastructure, fully captures the benefits of the infrastructure projects. The exception to this rule is related to the efficiency losses from taxation, or other price distortions.

Having said this, we must note that there are several subtleties in determining the shadow price, and that the "general equilibrium impacts" mentioned above add to these subtleties. The theoretically correct shadow price for the household sector is the reduction in expenditures that could result from an infrastructure increase, holding the consumer's level of utility constant. For the producer sector it is the incremental increase in profits that could result from an increase in infrastructure, either from increased sales or reduced costs. These shadow prices traditionally have been estimated from the "bottom up", using engineering studies to evaluate what are considered the elements of the shadow price, e.g. waiting time, operating and maintenance costs (O&M costs). An attractive alternative to this approach is to use econometric studies of infrastructure users to infer these prices. Econometric models of consumption and production, including infrastructure, could be developed. For example, a variable profit function of the transportation sector could be estimated. This function could then be differentiated to yield the shadow price function. To our knowledge, the application of econometric models to project evaluation has been limited.

The major subtlety in shadow price calculation is that the shadow prices are functions of other economic variables. Good practice would recognize these relationships and incorporate them. In the cases of technical change, returns to scale, price effects, and project complementarity and substitutability, we have explained how these relationships work. Ignoring some of these impacts would lead to an understatement of the gains from infrastructure investment and a corresponding under-investment. Others would lead to an overstatement and over-investment.

CHAPTER 5

CRITERIA FOR EVALUATING CURRENT PRACTICE

The previous Chapter establishes that if project-level economic evaluation is conducted in line with the correct theoretical and applied extensions, including appropriate allowance for complementary and substitutable projects in the selection project scope, the sum of accepted projects will equate to the optimum investment mix and level from the viewpoint of productivity and economic growth.

Is the current practice of economic evaluation correct? Are there consistent oversights in current practice causing under (or over) investment in infrastructure, handicapping growth in the national standard of living? To answer these questions, the next stage of this project will examine a representative sample of case studies. Identification of any consistent errors in practice provides guidance for preparing the Primer; evaluations also provide case study material that is used (anonymously) in the Primer.

PLAN OF THE CHAPTER

This section establishes criteria against which sound practice can be judged. The criteria are developed into complete guidelines for use in the Primer and used in Part II as a basis for assessing each case study and methodology.

Examples given under each criterion are divided into partial and general equilibrium factors. It should be noted that in practice, the distinction between partial and general equilibrium is artificial. Models used to estimate the benefits and costs of transportation projects will account for some variables, and assume other factors fixed. The greater the number of factors that are permitted to vary within a model, the closer that model approaches "general equilibrium".

In this case we have drawn the dividing line for general equilibrium considerations at the point where estimates of the demand for transportation (say total trips) change for reasons other than population or economic growth. In other words, the impact of lower transportation costs on the demand for transportation (movements either along the demand curve or shifts in the demand curve as indications of technical change and productivity growth-see Chapter 4) is considered a general equilibrium effect. Our preliminary evaluations indicate that many transportation investment studies treat demand for transportation as a fixed amount for any given forecast year. The feedback of infrastructure investment on demand is often neglected.

CRITERIA FOR THE EVALUATION OF SAMPLE STUDIES

The evaluation would proceed in two steps, as follows:

- o Evaluation of whether selected objectives are those that promote the contribution of transportation infrastructure to productivity, growth and living standards;
- o Evaluation of whether the adopted acceptance criterion and methodology was consistent with the selected objectives; and
- o Evaluation of whether the selected methodology was applied correctly.

Choice of Objectives

We propose to focus on:

- o The clarity with which objectives are stated;
- o Awareness of the correct meaning of different economic objectives; and
- o The extent to which objectives relate to productivity, growth and economic welfare versus distributional and re-distributional aims.

Our preliminary review and evaluation indicates that some decision-makers and practitioners state one objective while in fact favoring another. This will occur, for example, when an authority favors economic growth and welfare but mistakenly states employment maximization as the objective. The Primer examines the reasons for objective mis-specification and possible solutions.

Choice of Acceptance Criteria and Methodology

The taxonomy reported in Tables 1 and 2 (see Chapters 2 and 3) will be used to establish whether practitioners choose the acceptance criterion and methodology that is consistent with their stated objectives and with the objectives they in fact favor.

Where the incorrect criterion and methodology is selected, we will undertake the procedure outlined in the left-hand side of Figure 6 in order to demonstrate the difference in investment implications from choice of the appropriate approach. These cases will be used (anonymously) as examples woven throughout the Primer.

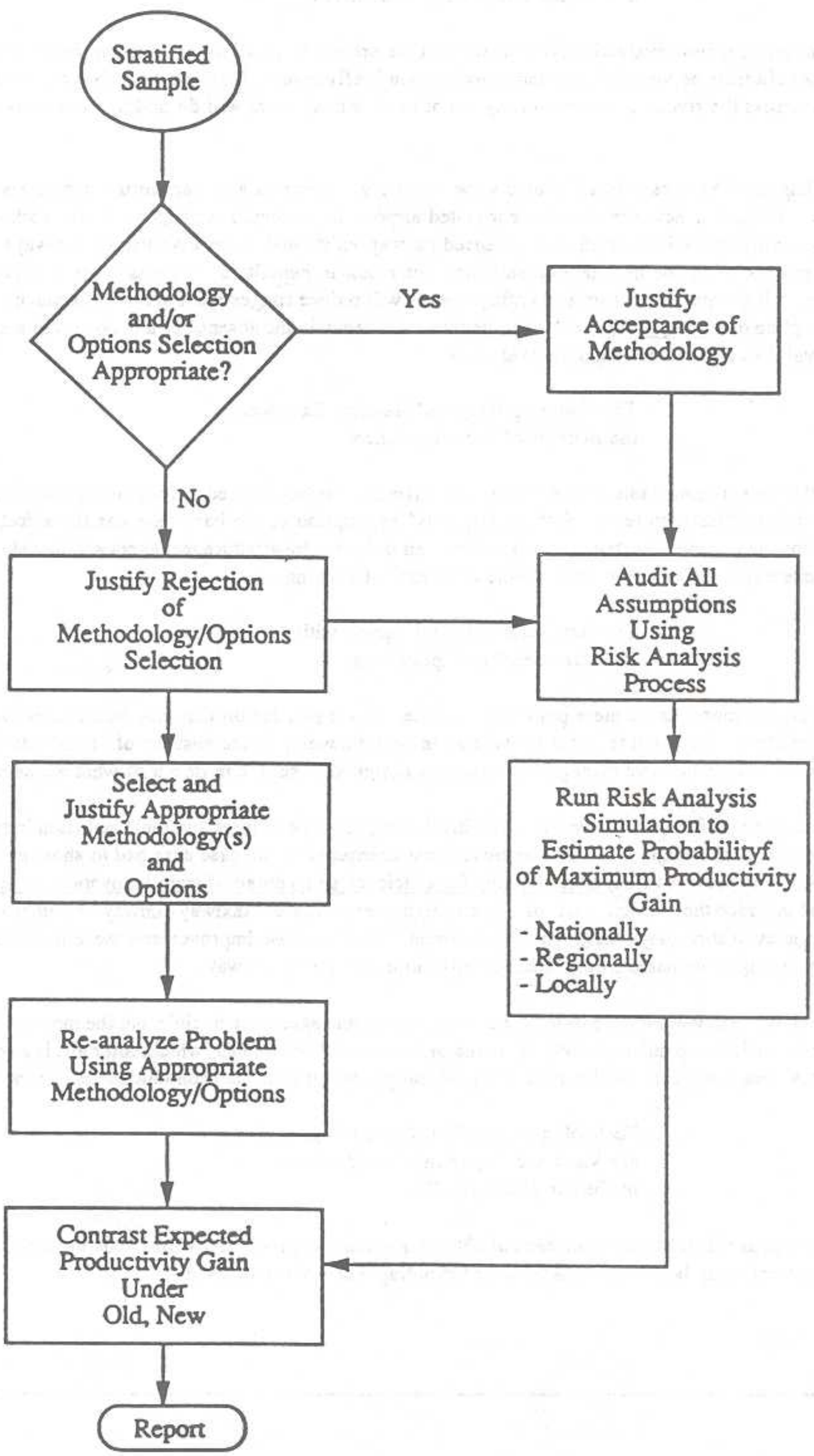
In cases where the incorrect methodology is selected, the reasons for improper choice is examined in the Primer in order to ascertain how best to resolve the problem.

Application of Methodology

Focusing on projects whose objectives-whether correctly stated or not-emphasize economic development, productivity and economic growth, we will conduct an evaluation to ascertain whether all impacts, (both partial equilibrium and general equilibrium) have been estimated in accordance with the prescription developed in Chapter 4. Where this is not the case, we will conduct the tests outlined in the right-hand column of Figure 6 in order to demonstrate the magnitude of the productivity gains that have been neglected in the analysis. These cases are used (anonymously) as examples woven throughout the Primer.

In addition, we will conduct an evaluation of basic procedure using the following evaluation criteria to guide the analysis (again, results are used anonymously as examples in the Primer). The criteria outlined below are presented in outline form. Part II will expand each into a complete guideline that is used in the Primer.

FIGURE 6: PROJECT ANALYSIS



TEXT BOX 1: GUIDELINES
IDENTIFYING THE BASE CASE IN INVESTMENT ANALYSIS

The "Nothing Happens" Base Case is a Basis for Comparing Alternatives

A common feature of many economic evaluations is that, without the project in question, nothing will be done to improve the problem at hand or to benefit from opportunities for improved economic efficiency. If government does not construct a bridge, traffic will be unable to cross the river. If a new runway is not built, management will do nothing to improve the operation of the present airfield.

Clearly, the "nothing happens" base case is a fictional view of how governments and transportation systems behave in the absence of investment. Without a new runway at a congested airport, for example, management will seek out other, less expensive ways of improving operations, such as high-speed runway exists and innovative use of taxiways. To be sure, improvements in the absence of major new investments may not result in benefits as large as those expected from major investment alternatives. A high-speed exit from an existing runway will reduce congestion, but not by as much as an additional runway. But the assumption that <u>nothing</u> will be done to improve efficiency in the absence of a major investment is obviously unrealistic and thus invalid as a basis for economic evaluation.

The "Nothing Happens" Baseline Exaggerates the Benefits of New Investment

Since some portion of the benefits obtainable from major new investments can be captured instead through innovation and sound management of the existing infrastructure, a "Nothing Happens" assumption in the base case has the effect of potentially exaggerating the need for major new investment. This in turn can deflect infrastructure managers and decision makers alike from seeking out and examining measures to improve the efficiency of existing assets.

The Base Case is a Real Option with Possible Spending Implications

Clearly then, the base case is more than a mere point of reference. It is a real option that may be characterized as a careful projection of how the existing infrastructure under consideration would develop in the absence of major new investment but with the guidance of sound and innovative management practices designed to get the most out of what we have.

Obtaining maximum productivity from current systems can involve capital expenditures and their inclusion in the base case is perfectly valid. In one example, a major $100 million investment alternative to the base case had to show benefits in excess of costs (that is, a positive net present value) <u>after allowing for efficiency gains obtained from innovation in the base case</u>. In another case, an airport included the capital cost of special high-speed exits and taxiway-runway link improvements in the base case of an economic evaluation major new runway proposals. The base case improvements were found to achieve fully 15 percent of the delay savings obtainable from a substantially more costly new runway.

The approach outlined above to developing the base case recognizes the management principle that the more efficiency we can seize from current assets, the less dependent we will be on major new capital investment, which, after all, is a scarce resource. The "something happens" base case ensures the most stringent and prudent test of the economic merit of new investment.

Technological and Non-Capital Improvements are Valid and Important Considerations in Defining the Base Case

In addition to moderate capital expenditures as a means of obtaining maximum productivity from existing assets, technological and non-capital improvements may be available as means of avoiding more costly investment.

- **Was the correct baseline identified?** (see Text Box 1 for example Primer guideline based upon this criterion)

  – Measurements of the economic efficiency of prospective investment require a basis for comparison. Properly defining the basis for comparison--called the "base case"--is no less critical to a valid economic evaluation than specifying the nature of the investment alternatives themselves.

  Partial Equilibrium Concerns.

  – Alternative administrative measures. For example, congestion at a tunnel may be eliminated by either building an additional tunnel, or simply raising tolls on the existing tunnel. Assessment of a new runway must show the runway to be superior to raising fees; and

  – Alternative technologies to provide the same net effect. Changing truck regulations to allow larger trucks may reduce the need for road expansion (at the expense of higher road maintenance costs and safety).

  General Equilibrium Concerns.

  – Timing. Technology sensitive investments tend to decline in cost over time. A project may be of positive value now, but be of higher net value if delayed. The correct criteria for implementation is when the decline in cost per year equals the lost benefits per year; and

  – Alternate technologies.

- **Was the scope of the assessment sufficient to capture interdependency with other transportation investments?**

  – Benefits and costs of one investment project may be affected by another. For example, the benefits of a new highway interchange might be greater if the highway is also widened. The scope of Benefit-Cost Analysis exercise should be sufficient to allow consideration of all relevant strategic choices in transportation investment.

  General Equilibrium Concerns:

  – Project complementarity. Assessment should account for the impact of other projects which have a positive impact on the benefits of the project understudy; and

- Project substitutability. Assessment should account for other projects which can substitute for the one under study. For example, improved rail transit might reduce the need for bus facilities.

o **Were all relevant categories of cost and benefit identified?**

- Examples of categories to be accounted for include:

  - Congestion costs imposed on other transportation systems. Does a state highway increase/reduce congestion in a downtown core?; and
  - Scale economies/diseconomies outside of the actual transportation facility and its immediate users. Increased traffic flow may result in urban growth and a lowering/raising of average costs for some industries in the city.
  - Passenger time savings. This is often neglected when accounting for reduced or avoided congestion and delay;
  - Reduced inventory (the equivalent of passenger time savings for freight);
  - Safety gains in life and limb;
  - Benefits and costs to those outside the funding jurisdiction;
  - Noise costs;
  - Water table/water shed impacts; and
  - Wild-life impacts.

  General Equilibrium Concerns:

  - Land use. Restriction/enhancements of use of surrounding land. This is often captured through property values, or through the additional expenses required to preserve existing uses;
  - Utilization excess capacity in other industries. The example of most concern is net increases in employment due to the elimination of structural unemployment in underemployed sectors

– Impact of quality improvements. The new project may change the underlying nature of the transportation service being provided. Existing users may place a higher value on the service because of the increase in quality. For example, a new highway which shortens distance between two points may provide benefits beyond the savings in operating costs to those using it. Trucking firms may now offer one-day service where before they could not. Business travellers may now be able to make trips in one day and spend more time with their families.

o **Did forecasts of transportation demand account for all relevant factors?**

– Demand forecasts are the most uncertain and difficult task facing project evaluation. While costs of undertaking a project are relatively well known from past experience, the volume of benefits is driven by expected future demand. Factors which should be accounted for include:

Partial Equilibrium Concerns:

– Economic and demographic conditions. Demand for transportation is driven by population and economic activity. Simple trend lines over time are not acceptable. Historically, taking time trends during high growth periods has lead to large overestimates of future needs.

General Equilibrium Concerns:

– Feedback of Improved Infrastructure on Demand. Reduced congestion or improved facilities will cause an increase in the demand that would have otherwise being forecast;

– Price effects from elsewhere in the economy. Prices of other goods and services will influence transport demand. For example, high oil prices will reduce most transport demand;

– Technical change in infrastructure. The investment project may embody technical improvements over whatever it is expanding/replacing. These improvements may have an impact on demand;

– Technical change in transportation using industries. Changes to industry practice may increase/reduce demand for transportation infrastructure. In particular, technical change in the transportation

– Technical changes elsewhere in the economy. For example, the use of fax machines may reduce the demand for courier services.

o **Were major sectoral and distributional issues adequately explored and disclosed?**

– Distributional issues should be identified and discussed. They do not directly affect the calculation of net benefits and costs, but they are important for two reasons. First, distributional issues are inevitably of concern to decision-makers. Second, they identify affected stake-holders in ways that can reveal missing elements in the Benefit-Cost Analysis.

o **Was the flow of costs and benefits over time correctly treated?**

– Typically, transportation projects require investment now for benefits later. Because a dollar tomorrow is not worth as much as a dollar in hand today, costs and benefits in future years must be "discounted" to comparable worth today. The farther in the future a benefit or cost is, the more it is discounted.

– The accepted approach is to calculate the "present value" using an appropriate rate of interest called the "discount rate". For example, at a discount rate of 10%, $1.10 one year from now is worth only $1.00 today.

Partial Equilibrium Concerns

– Was the period of time used to evaluate the project long enough?;

– Was account taken of any significant benefits still accruing at the end of this time period (i.e. "salvage value").

o **Was the correct discount rate used?**

– Choice of the correct discount rate is important. If the rate is too high, we will wrongfully reject projects whose benefits are concentrated in the long run. If the rate is too low, we will accept projects whose benefits are too far in the future to justify investment today;

– The correct discount rate for public projects has been a subject of continuing debate. However, there is consensus that it is less than the average rate of return to private capital, and more than the rate of interest implied by consumer saving behaviour. Some estimates have placed it

Partial Equilibrium Concerns:

- The discount rate should be stated in "real" terms. This means that inflation should not be included; and

- The discount rate should be applied to "real" numbers. The effects of anticipated inflation should be removed before discounting. If the base year is 1986, then all future costs and benefits should be stated in 1986 dollars before discounting.

General Equilibrium Concerns:

- Risk adjustment. If appropriate, the discount rate should be adjusted for risk. "Risk" in this case is not the uncertainty of project costs or benefits. Instead, it is an adjustment made if the net benefits of the project are unusually highly correlated with the health of the economy; and

- The correlation should be unusually high because all transportation projects will have net benefits correlated with the economy. This adjustment is rarely done.

o **Was net present value used as the decision criterion? If net present value was not used, as in a cost-effectiveness study, was the case established that the net present value could be expected to be positive?**

- Net present value is the only correct criteria for judging whether a project is worth undertaking. Internal rate of return and benefit to cost ratios are known to be inferior. Using them may result in accepting bad projects and rejecting good ones. If capital funds are limited, and all projects with positive net present value cannot be funded, then the correct approach is to fund those projects with the highest net present value per dollar of investment; and

- On occasion, a full Benefit-Cost Analysis study is not done. Instead, the objective of the investment is assumed to be worthwhile, and the most cost effective means of providing the investment's function is sought. In these cases, it should be demonstrated that there is strong reason to believe that the net present value of the project is positive, even if such a calculation is not undertaken. All other criteria still apply.

- **Was the risk and uncertainty in results explored and tested?**

  - All Benefit-Cost Analysis assessments will have weak points in their data and assumptions. The sensitivity of the overall conclusions should be tested to see if alternative assumptions or variations in the data affect the conclusions. Methods to do this include sensitivity analysis, and Monte Carlo analysis; and

  - If there is substantial risk that one of the assumptions is not valid, or of an alternate value, then the estimate of net benefits should be reduced to account for this possibility.

- **Were any departures from normal standards of practice adequately explained?**

  - If there are special circumstances causing the study to vary from the criteria established above, they should be explained and justified.

Common Standards

In assessing the sample studies, an assessment will also be made of the standard values being employed by studies. We anticipate that there is substantial variation in the values employed by studies for:

- social discount rate;

- value of time; and

- value of life.

Variation in these key values, which should be the largely the same across the U.S. economy, would identify a need for common standards. In addition, it is possible that the values typically chosen are too high or too low, affecting the aggregate level of investment in transportation infrastructure.

CHAPTER 6

CONCLUSIONS ON TECHNICAL PRINCIPLES

As a foundation for the Primer to be developed in Part III, this Part addresses four principal questions;

- The economic objectives of infrastructure investment;
- The relationship between objectives and the choice of appropriate methodology for evaluating infrastructure investment;
- The capability of methodologies to measure in-full all relevant economic impacts; and
- The valid and effective application of appropriate methodologies.

This Part also presents a plan to evaluate current practice in order to ensure that the Primer is targeted to areas of essential and practical need in the field.

DIFFERENT OBJECTIVES REQUIRE DIFFERENT METHODOLOGIES

Different economic objectives for transportation infrastructure investment call for the application of different methodologies to measure progress towards them. This Part begins by identifying the relationship between alternative economic objectives for transportation infrastructure investment and the specific methodological approaches needed to ensure their achievement.

PRODUCTIVITY AND GROWTH AS OBJECTIVES OF TRANSPORTATION INFRASTRUCTURE

Productivity and growth are found to be quantitatively significant outcomes of infrastructure investment. Methodologies that identify such impacts are critical in infrastructure planning. As ends in themselves, however, productivity and growth are found to be inappropriate as the stated objectives of infrastructure investment and as the basis for methodological choice. Productivity and growth as objectives imply the acceptance of any project with a positive rate of return. There is no evidence that the United States has ever accepted an investment rule that effectively equates the social cost of capital to zero--a rule that accepts any reduction in current consumption, leisure standards, environmental quality and general living standards in order to achieve an increment of future growth.

This Part finds that productivity and growth are optimally promoted through the broader investment objective of "welfare maximization"--the maximization of all economic benefits net of the economic costs of achieving them, where future benefits and costs are properly adjusted (discounted) to reflect the desired trade-off between higher living standards now versus the future (the social opportunity cost of capital). It is found that while the faster growth rates of certain competitor-nations may be attributable to the absence of such an investment policy, the United States has achieved, and can perpetuate, competitive levels of productivity and growth through investment without a fundamental shift away from the welfare criterion.

DEFINING ECONOMIC DEVELOPMENT IN THE CONTEXT OF TRANSPORTATION OBJECTIVES

This Part recommends that the term "economic development" be defined in the context outlined above. Economic development may thus be said to occur whenever a project or collection of projects yield discounted economic benefits in excess of discounted economic costs (i.e. when the net present value is positive after applying a discount rate that reflects the social opportunity cost of capital). The state and national level of productivity, growth and economic development for which to aim in relation to transportation infrastructure investment is the level that stems from the maximization of discounted net benefits. Maximizing economic welfare in this sense means promoting a growth rate in productivity and GNP that is consistent with the highest possible standard of living.

APPROPRIATE METHODOLOGY FOR GAUGING TRANSPORTATION'S CONTRIBUTION TO PRODUCTIVITY AND GROWTH

Among the range of available methodologies, Benefit-Cost Analysis is found to be the most appropriate in the context of optimizing transportation's contribution to productivity and economic growth through welfare maximization. Other methodologies are found to be useful in ascertaining the distributional (income, regional and sectoral) implications of alternative mixes and levels of investment. Distributional methods, in themselves, signal nothing about transportation's ability to foster improved productivity and growth.

This Part concludes however that there are serious gaps between Benefit-Cost Analysis as traditionally conceived and practised (a partial equilibrium framework) and the need to identify the full range of productivity and growth impacts of transportation infrastructure projects (general equilibrium effects). This is found to be the case in both theory and practice. These shortcomings lead us to conclude that the sum of all infrastructure decisions taken according to traditionally conceived rules and applications of Benefit-Cost Analysis will fail to achieve the level and mix of transportation investments that optimize productivity and economic growth from a regional and national perspective.

METHODOLOGICAL ADVANCES

However, theoretical advances and advances in estimation techniques that are offered in this Part provide proof that suitably modified, the Benefit-Cost Analysis framework will capture, comprehensively, all impacts of relevance to productivity and growth. This Part develops the theoretical basis for establishing new rules of estimation that, in practice, will ensure the identification of the full range of benefits.

This Part moves toward development of productivity impact "correction" factors. Developed from econometric models such as those of Aschauer, from variable-coefficient input-output models and related dynamic techniques, such factors are presented in the Primer and intended for the use of practitioners. This approach appears superior--or at least a necessary supplement--to recommending field application of the complex and time-consuming methodologies needed to develop such corrections for each specific study. We find that, while preliminary factors by mode and type of project can be developed for the Primer, additional research will be needed to fully develop them. Once fully developed, the Primer can be updated accordingly.

EVALUATION PLAN FOR PART II

This Part presents a wide range of criteria for use in the evaluation of current practice in Part II and a plan for establishing the structure and content of the Primer, to be developed in Part III. The criteria ask how decision-makers select the economic objectives of infrastructure investment; how practitioners select evaluation methodologies, and whether objectives and methodologies are properly linked; and how accurately and effectively methodologies are applied in practice. This understanding is needed to ensure that the Primer is targeted to areas of essential and practical need in the field.

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SUPPLEMENT TO NCHRP REPORT 342

TECHNICAL REPORT

PART II

1990 SURVEY OF CURRENT PRACTICE

CHAPTER 7

INTRODUCTION

Part I identified and described the range of methodologies available to analyze the relationship between transportation and the economy. That Part identified and evaluated appropriate methodologies in relation to alternative economic aims of infrastructure investment, with special reference to the promotion of productivity and growth.

In a preliminary evaluation, Part I found evidence of mis-matches between the stated objectives of proposed infrastructure projects and the objectives of infrastructure investment from the viewpoint of productivity and growth. The preliminary evaluation also found evidence of mis-matches between the objectives of infrastructure investment in promoting productivity and growth, the choice of evaluation methodology and the use of related technical procedures.

To complete the preliminary evaluation, and to ensure that the Primer is well targeted as a means of resolving difficulties in the field, Part I developed a procedure for the evaluation of current practice and a method for developing case studies. The procedure calls for the evaluation of a sample of project appraisals in terms of several criteria. The criteria require the examination of how decision-makers select and state the economic objectives of infrastructure investment; how practitioners select evaluation methodologies, and whether objectives and methodologies are properly linked; and how accurately and effectively technical procedures are applied in practice.

Part II applies the evaluation-design developed in Part I to a representative sample of case studies. The evaluation is designed to provide case material for use in the Primer and the identification of consistent errors will be used in developing the "inventory of common errors" required in each Chapter of the Primer.

It should be noted that with the Primer being prepared in parallel with this Part, (including case studies and examples of sound practice and inventories of common errors drawn from the evaluation) not all of the evaluation material is presented here as well. Rather, the intent of this Part is to summarize salient features of the evaluation, provide examples of key findings and highlight the implications of the evaluation for policy and practice.

PLAN OF PART II

Part II is presented in seven Chapters. Chapter 8 reviews the analytical approach and the size and composition of the sample used in the evaluation. The analysis begins in Chapter 9 which considers the objectives stated in the project case studies and asks whether selected objectives are those that promote productivity, growth and economic welfare through infrastructure development. Chapter 10 establishes whether practitioners choose project acceptance criteria and assessment procedures that are consistent with the economic objectives of infrastructure investment. Chapter 11 then focuses on the application of technical procedures.

Chapter 12 looks specifically at the identification of the "general equilibrium impacts" of public infrastructure. Part I finds that conventional methods of assessing the productivity implications of public infrastructure projects have not yet incorporated measures of certain payoffs in the private sector that translate into greater overall growth and living standards. Finally, Chapter 12 assesses the implications of this finding in the context of current practice.

Three Appendices relevant to Part II appear at the end of the Technical Report. Appendix B presents a sample evaluation form used to assess the case studies. Appendix C provides details of the evaluation criteria used in assessing the case studies.

CHAPTER 8

PROJECT SAMPLE AND ANALYTIC APPROACH

This Chapter presents the sample of projects chosen for evaluation and the analytical approach. With the exception of certain projects being added to the sample, it draws from the design established in Part I.

PROJECT SAMPLE SELECTION

The range of selected projects is presented in Figure 7. The sample was drawn from a larger universe using the stratification scheme presented in Figure 8. The following criteria were considered in selecting the sample projects:

- **Location and Scale** covering national, regional and local projects and project size;
- **Mode and Type** covering highway, public transit, rail, ports, airports and inland waterways. Project "type" covers construction, reconstruction and repair; and
- **Point of Approval** including appraisals in progress, projects rejected on the strength of appraisal results and projects approved for construction (including completed projects, projects in-progress and those not started).

The sample includes a number of projects now under active consideration (the Paradise Parkway-SR 50 highway program, Phoenix). We have visited Phoenix and briefed the Arizona Department of Transportation (ADOT) in depth regarding NCHRP Project 2-17(1) and ADOT officials have agreed to our use of the Paradise project. Other active projects include the Federal Aviation Administration's National Airspace System Plan and the Toronto Transit Commission's Spadina Subway Extension.

The study sample includes 35 projects covering 10 airport and air traffic control-related projects, 10 highway projects, six public transit proposals, two high speed rail systems, five ports, and two inland waterway projects.

CRITERIA FOR THE EVALUATION OF SAMPLE STUDIES

The analytic approach used in this evaluation was developed in Chapters 5 and 6 of Part I, Technical Principles. The evaluation was undertaken in three steps as follows:

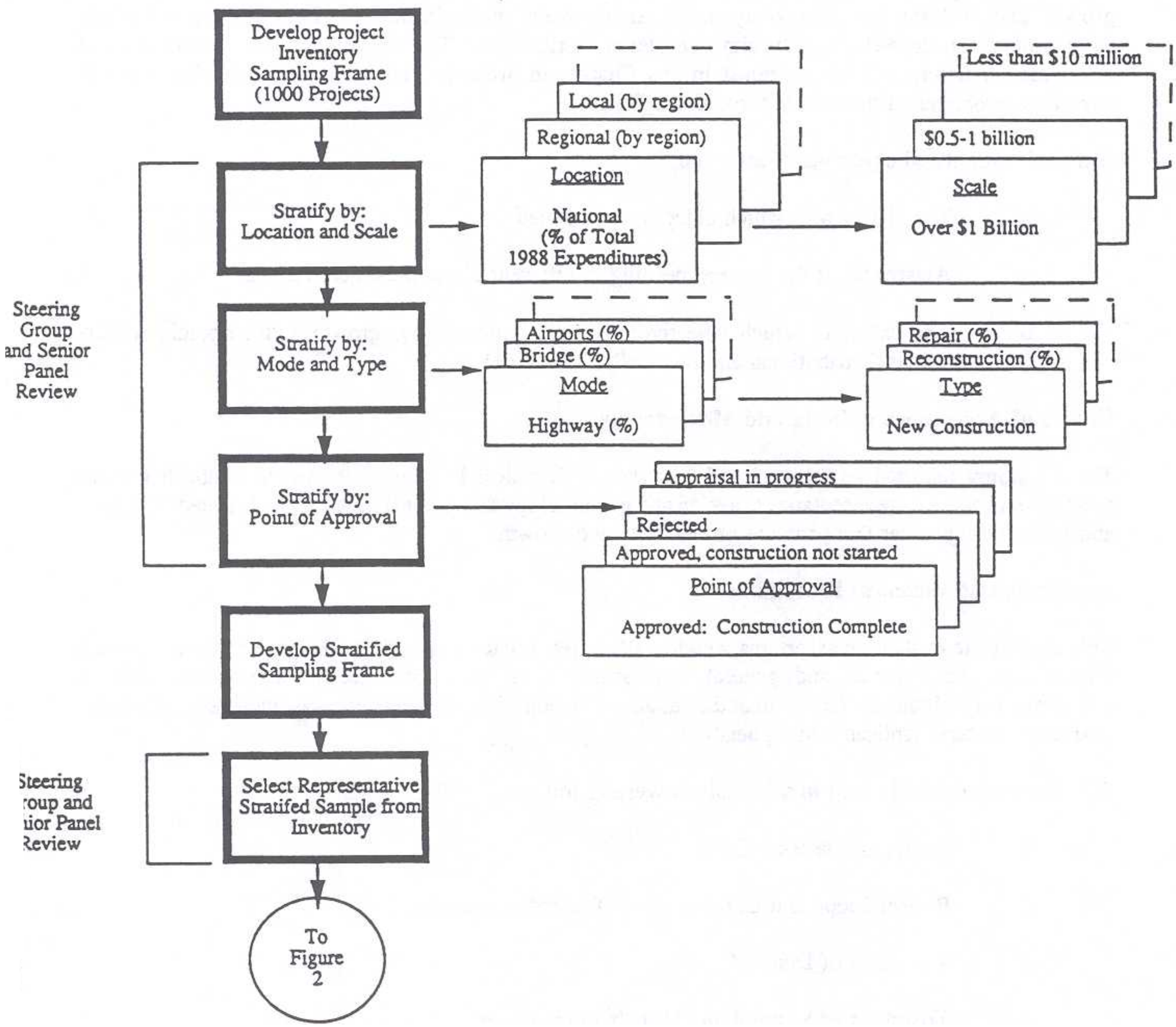
- Evaluation of whether selected objectives are those that promote the contribution of transportation infrastructure to productivity, growth and living standards;
- Evaluation of whether the adopted acceptance criterion and methodology is consistent with the selected objectives; and
- Evaluation of whether technical procedures underlying the selected methodology are applied correctly.

FIGURE 7: SELECTED PROJECT EVALUATIONS BY MODE AND SCOPE

GEOGRAPHIC SCOPE	MODE					
	AIR	HIGHWAY	PUBLIC TRANSIT	RAIL	PORTS	INLAND WATERWAY
LOCAL	Bird Island Flats, Logan Airport Andalusia, AL Airport Expansion of [redacted] Airport [redacted] Airport	[redacted] Highway Project, [redacted] North Foothill Drive, Spokane Maine Turnpike	BART Subway Extension BART Subway Extension Long Beach, Los Angeles Rail Transit [redacted] Bus Tunnel		LNG Terminal, Everett, MA Boston Marine Industrial Park	
STATE		North Belt Freeway, N. Little Rock WA State Rte. 2/26, Wenatchee NC State Rte. 280 Maricopa County Paradise Parkway Program, AZ	[redacted] [redacted] Corridor Bus/HOV, [redacted]	[redacted] High Speed Rail Florida High Speed Rail (privately funded)	Multipurpose Deepwater Port, [redacted]	[redacted] Waterway
FEDERAL	Transport Canada Radar Modernization Program [redacted] National Aerospace System Plan [redacted] International Airport, [redacted]	Central Artery/ Third Habor Tunnel, Boston Beltway 8, Harris County, TX Interstate Highway Maintenance (4R) Program (Congressional Budget Office)	Dade County Rail MARTA System Southwest Transit Corridor, Chicago		Tampa Harbor [redacted] Harbor Channel Improvements	[redacted] River Navigation System

[redacted] Denotes Anonymity

FIGURE 8 : PROJECT SAMPLE SELECTION



Choice of Objectives

Our preliminary review in Part I indicated that some decision-makers and practitioners state one objective while in fact favoring another or fail to identify economic objectives that are consistent with productivity and economic growth. This was found to occur, for example, when an authority favored economic growth and welfare but mistakenly stated employment maximization as the objective--or where employment was indeed the only aim considered worthwhile. The reasons for this specification of economic objectives will be examined in this Chapter in order to find the most appropriate ways to overcome problems of this nature through the Primer.

Our review of stated objectives focuses on:

- The clarity with which objectives are stated;
- Awareness of the correct meaning in different economic objectives; and
- The extent to which objectives relate to productivity, growth and economic welfare versus distributional and re-distributional aims.

Choice of Acceptance Criteria and Methodology

The taxonomy reported in Tables 1 and 2 of Part I, Technical Principles, is used to establish whether practitioners choose the acceptance criterion and methodology that is consistent with their stated objectives and with the objectives that promote productivity and growth.

Application of Technical Procedures

This step of the evaluation ascertains whether all project-related impacts of relevance to their economic implications, both partial and general equilibrium, have been estimated in accordance with the prescription developed in Part I. In addition, an evaluation of basic procedure was undertaken, using the evaluation criteria replicated in Appendix C

B. The major criteria used in this analysis were as follows:

- Design of the Base Case;
- Project Scope and Consideration of Interdependencies;
- Treatment of Demand;
- Treatment of Sectoral and Distributional Issues;
- Treatment of Timing and Discounting;
- Treatment of Risk and Uncertainty; and
- Use of Standard Values.

Each of these major criteria are treated in separate sub-sections, in Chapter 11.

ANALYTIC APPROACH TO THE EVALUATION

Described in detail in Part I, the analytic approach presented in Figure 3 guided the appraisal of sample projects. Projects were assessed and the results documented using the detailed format and evaluation form shown in Appendix A.

Two levels of evaluation were conducted, a primary level and a secondary (or "special") level. Primary evaluations include an assessment in terms of each criterion and a counter-factual analysis to determine whether the correction of errors and omissions would change the conclusions of the evaluation. Secondary and special evaluations looked at certain questions in particular, and were reserved largely for projects that were not relevant to certain aspects of the evaluation. These would include, for example, projects that conducted only multiplier analysis of employment impacts in which case criteria pertaining to the use of Benefit-Cost Analysis could not be applied. In total, 15 primary evaluations and 20 secondary and special evaluations were carried out.

CHAPTER 9

THE CHOICE OF OBJECTIVES

The specification of economic objectives for infrastructure investment is not always easy or obvious. Indeed, our assessment has indicated that it is a source of considerable confusion. There is growing concern, for example, that transportation investment policies are not providing the necessary level, type or quality of service required to maintain or improve national productivity and growth. Does this mean, however, that enhanced productivity and growth are valued for their own sake? Or is growth a means of achieving the broader economic purpose of improved living standards? Failure to recognize this distinction can result in policies that promote investment-led growth at the sacrifice of current consumption and possible social and environmental risks that diminish living standards. The related methodological problem (which will be explored in the next Chapter) is that mis-specification of economic objectives can lead to the choice of methodologies which in effect answer the wrong questions and promote inappropriate policies.

EVALUATION CRITERIA

Part I identified welfare maximization as the appropriate economic objective of transportation infrastructure in enhancing productivity and economic growth while simultaneously promoting improved living standards. Increased economic welfare is defined to occur when a change (such as an investment in transportation) yields economic benefits--to both individuals and firms--whose economic value exceeds the economic costs of achieving them. Cost is defined to include all social and economic gains and living standards forgone as a result of the investment in question. The appropriate methodology for measuring the contribution of infrastructure to productivity, growth and living standards was found to be Benefit-Cost Analysis (suitably modified to accommodate private sector benefits that translate into public gains).

Part I concludes that growth may be accepted as an end in itself only if the nation (or any sub-national geographic region) is willing to risk the sacrifice of certain living standards in order to expand production and output. Some analysts argue that Japan has taken this course, achieving high growth at the expense of environmental quality, living space, commuting time and so on. Part I concludes that Benefit-Cost Analysis (with certain extensions--see later) is the appropriate methodology to establish a project's contribution to the welfare objective.

Like production and growth, economic welfare can be measured at any geographic level. Economic welfare is distinct from the value of total production, however, in that the latter is restricted to goods and services that are bought and sold in the marketplace. Economic welfare, defined in terms of benefits and costs, also accounts for items for which there is no market but that nevertheless occasion economic value in the sense that people are willing to pay to acquire or avoid them. Such items include time savings, leisure time, improved health, environmental damage and so on.

The objective of economic welfare also accounts for the way individuals value present consumption over investment for future consumption. This is achieved in Benefit-Cost Analysis through the use of the "social discount rate"--a factor that translates the value of all future costs and benefits into their present-day worth (commonly termed "present value").

GENERAL FINDINGS

Our general findings on current practice with respect to the specification of economic objectives may be summarized as follows;

- A total of 47% of the projects reviewed failed to specify "increased economic welfare" or related concepts as their objective;

- In all, 27% of projects failed to identify "increased economic welfare" as their primary objective, but did specify a number of secondary objectives that support the goal of increased economic welfare;

- A total of 13% of the projects specified multiple objectives without distinguishing primary and secondary aims; and

- 13% of the projects identified increased economic welfare or closely related concepts as their primary objective.

It thus appears that a small minority of practitioners and decision-makers in the field focus on the economic objectives of productivity, growth and enhanced living standards as either the principal or secondary purpose of infrastructure investment. More often than not, the economic objectives of infrastructure investment are couched in terms of employment and redistribution. As shown in Part I, these are worthy economic aims but in themselves do nothing to promote improved productivity and growth in output, or access to higher living standards for larger numbers of people.

In addition to the above, the analysis indicates that many project evaluations do not choose techniques for assessment that are appropriate to the aim of enhanced productivity, growth and enhanced living standards.

Taken together, the findings reported here have serious implications for the use of infrastructure capital. They imply, for example, that even had infrastructure spending been substantially greater over the past 20 years, the related potential for improved national output would have been neither optimized nor realized to a very great extent. Similarly, current practice implies that a major increase in current levels of infrastructure investment would not yield returns sufficient to justify the expenditures.

The findings also indicate that the stimulus to productivity and growth available from infrastructure investment would increase significantly from a redirection of current practice in selecting objectives and evaluating choices. The case studies suggest that in order to select the appropriate methodology in any given situation, policy makers and practitioners require:

- A clear understanding of the various economic objectives that infrastructure investment may serve to promote;

- A clear understanding of the economic objectives implicit in the use of alternative evaluation methodologies; and

- A clear and valid framework for selecting desirable economic objectives and identifying and using the correct methodologies for use in measuring their achievement.

It is critical that the Primer responds to these needs.

CASE STUDY EVALUATION AND COUNTER-FACTUAL ANALYSIS

In the case of those projects which failed to specify increased economic welfare as their objective, the tendency was to specify growth in total employment and regional transfers as the principal aims. Two examples, Case 22, a public transit project, and Case 3, an airport project with national implications, are reported below.

Case 22: Public Transit Project

The stated objective given in Case 22, a public transit project, is given as follows:

> "There are a number of economic impacts of transit which extend beyond the transportation system. In particular, location of future activities is affected by the significant changes in the regional pattern of accessibility which a transit system introduces. The transit system provides the greatest economic gains in the central portion of the region, high intensity activity areas and in the immediate vicinity of station areas. There are two basic impacts that have a number of desirable consequences:
>
> 1. A more concentrated pattern of development means that less land is converted to urban use and that public infrastructure costs are reduced.
>
> 2. The attraction of investment to the center of the region means that job opportunities are increased for the Center city low-income population and the base revenue position of the City is improved.

The objectives outlined above are largely redistributional, focusing on employment increases in the downtown core without addressing the **incrementality** of these impacts--whether the employment would substitute for jobs elsewhere in the region. The employment focus fails to recognize the congestion costs of downtown core concentration and thus disregards the efficiency and productivity implications of the investment.

Using counter-factual analysis, the nature of the data provided in the report makes it impossible to establish by conventional methodological means whether the selected alternative contributes to net economic benefits to the region or whether net benefits could be increased by applying the same volume of capital to another alternative. Heuristic risk analysis of the project indicates, however, that other uses of the funds, either for transit or other infrastructure options, have more than an 80 percent likelihood of outperforming the selected alternative.

Case 3: Airport Expansion

The objectives of case 3 were formulated as follows:

> The problem addressed is an immediate need for increased airfield capacity to reduce delays and congestion of aircraft operations. The existing runway system is not laid out for the most efficient handling of this high air traffic demand ....
>
> ... has recognized this problem and agreed that the need for increased airfield capacity in the form of additional runway capacity has been clearly demonstrated ... The Preferred Alternative is an east-west runway ... The Preferred Alternative has less adverse economic impacts than the other alternatives, and it has less noise impacts on surrounding communities. It also reduces wetlands and habitat loses as compared to the other alternatives ... The Preferred Alternative is viewed as a reasonable alternative that does minimize adverse impacts, and considers public concerns.

The key objective stated in this Case is reduced traffic congestion and delay, although other aims are also specified. The methodology used, however, was one of assessing the least environmental impact (damage) among the various options. The assessment in this case did not consider the economic benefits of reduced congestion and delay.

The key observation here is that while reduced congestion, delay and increased noise and environmental impact do indeed represent real economic benefits, costs, productivity, and growth, the objective was not translated into a methodological approach that measures these benefits and costs as a basis for establishing the net economic benefits of the project. Operational concerns thus underpinned the objectives, not productivity, growth or living standards. As a result, there is no evidence that the selected alternative provides economic benefits that exceed its economic costs.

Further evidence that operational as distinct from economic concerns dominated the objectives of Case 3 stem from the failure to consider the runway option in the context of a potential new airport being considered for the region. In the appraisal conducted by practitioners in Case 3, there is no allowance for the possibility of a new airport concurrently being considered for the metropolitan area in question. The same body had commissioned an economic impact assessment (Case 4) of a new airport for the metropolitan area. Case 3 was, however, considered in isolation of Case 4.

Counter-factual analysis indicates that, considered together, the economic returns of a new runway could be substantially affected by the timing of a new airport, particularly if the existing airport is to be closed. Only if the economic implications of airport development in the region had been a key objective would a methodology have been selected that accounted for substitute and complementary planning options, such the consideration of a new runway in the context of new airport development.

As documented above, a number of projects identify multiple objectives without specifying any as primary. Cases 19 and 23 identify 12 and nine objectives respectively. Both identify reduced congestion, the creation of employment opportunities, facilitating urban development, economic growth to the downtown core, low cost affordable transport to consumers, development in the most environmentally friendly manner, and increased public transport and decreased automobile use and thereby reduced pollution. Neither of these cases apply appropriate methodology from the viewpoint of maximizing productivity and growth.

Projects that specify a number of sub-objectives related to the aim of increased economic welfare do in turn apply aspects of Benefit-Cost Analysis. These tend to be marked, however, by flawed application of principles and technique, apparently in order to accommodate other concerns and non-economic objectives. Examples of such projects include Cases 27, 33, 34 and 35. The methodology used in these assessments fails, for example, to recognize the time phasing of benefits and costs (see later), apparently because other factors of concern cannot be viewed temporally. The fusion of alternative approaches does not, however, result in valid information for decision-making purposes.

Only a small proportion of projects identified increased economic welfare as their primary objective. A few illustrative points are drawn from Case 7 in the paragraphs below.

Case 7: A National Airport Project

Case 7, an airport capacity project, identifies increased economic welfare specifically as its primary objective. Selection of the economic welfare objective lead explicitly to the selection of Benefit-Cost Analysis, which in turn sought to identify the alternative with greatest net present value.

Case 7 is of further interest because it identified a possible second airport as one of the alternatives for expansion of airport facilities. It is in fact a similar situation to Case 3 where focus on immediate operational problems as distinct from economic concerns led practitioners to ignore key complementarities and interrelationships among options. The two cases thus provide an interesting contrast. Case 7 had selected the desired economic objectives and identified the correct methodology for use in measuring achievements. Case 3 had not. At the same time, Case 7 established that with the construction of a new runway, a new airport in the planning period would not be economically worthwhile from the viewpoint of productivity, growth and improved living standards. While the same might be true in Case 3, practitioners and decision-makers do not have sufficient information upon which to decide.

CHAPTER 10

THE CHOICE OF ACCEPTANCE CRITERIA AND METHODOLOGY

As indicated in Part I, different methodologies measure different aspects of the interrelationship between transportation and the economy. The choice of methodology in infrastructure evaluation and decision-making thus rests critically upon what aspect of economic activity policy is attempting to influence. The fact that an impact study for an airport or highway project forecasts a given number of direct, indirect and induced jobs, for example, does not mean that its construction would foster the objective of improved productivity and growth in national or regional output; a rate of return study would be needed to ascertain the latter. And if the rate of return study indicated that economic growth would result from the investment, this in itself would say nothing about the project's implications on standard of living; an answer to this question would call for a Social Benefit-Cost Analysis.

EVALUATION CRITERIA

Under the objective of welfare maximization, any project with a positive net present value may be regarded as acceptable in the sense that it can be expected (uncertainty aside) to yield productivity and growth-related benefits in excess of the costs of achieving them.

Net present value is the sum of all economic benefits over and above those likely to be achieved in the Base Case discounted to their present value at the social discount rate, minus the sum of all economic costs over and above those incurred in the Base Case also discounted to their present value. If the present value of the benefits minus the present value of the costs--the net present value (NPV)--is greater than zero, the investment may be considered a worthwhile contribution to the economy.

A positive net present value means that a project contributes positively to both productivity and growth and economic welfare generally. As an acceptance criterion, net present value rejects projects in which the value of any contribution to productivity and growth is less than the economic costs to be incurred in achieving that contribution. The validity of the net present value criterion also hinges on the correct identification of the social opportunity cost of capital and the full identification of all positive contributions to productivity in the estimation of net present value.

Where budgets are constrained and capital rationed, projects with the highest net present value may be ranked above those with lower net present values. Where limited budgets means that very expensive transportation infrastructure projects are at risk of crowding out less costly high-NPV projects in a capital budget, the literature indicates that ranking projects according their ratio of NPV to total capital cost (i.e., maximum NPV per capital dollar) provides a basis for allocating limited funds. This ratio may be regarded as a means of ensuring a "balanced" capital program; in accepting projects with lower over higher NPVs, however, the rule causes a deviation from maximum economic contribution of transportation infrastructure.

GENERAL FINDINGS

Our general findings may be summarized as follows:

- The majority of the projects examined (67%), did not use net present value as the acceptance criterion; and

- ○ About one-third did use net present value or a related measure as an acceptance criterion. In relation to the earlier finding that only 13 percent of all cases recognize welfare maximization as an objective of infrastructure investment, this finding is encouraging. It indicates however that the underlying meaning of Benefit-Cost Analysis and its related net present value acceptance criterion is not well understood in the field.

Where net present value is used, case study evaluations and counter-factual analysis indicates that when the net present value is applied in the absence of such understanding, technical procedures are typically applied improperly. Common errors include incorrect discounting procedures, improper specification of time horizons, inadequate quantification of benefits and mis-specification of the Base Case.

CASE STUDY EVALUATION AND COUNTER-FACTUAL ANALYSIS

The counter-factual analysis of two projects, Case 34 and Case 27 help, elucidate the general findings outlined above.

Case 34: State Public Transit Project

This Case illustrates the problems that arise in failure to adopt the net present value criterion. It also illustrates that net present values can be estimated from the same data used in most cost-effectiveness analyses.

Project analysts had examined five major transit alternatives relative to a Base Case defined by a transportation system management (TSM) plan for improving traffic flow in a metropolitan commuting corridor. The five options included;

- ○ A "Super TSM" plan;
- ○ Two alternative express bus alignments; and
- ○ Two light rail transit alignments.

The evaluation methodology used was based upon the Urban Mass Transportation Administration's (UMTA) cost-effectiveness guidelines; the guidelines recommend use of "cost per new transit rider" as the decision criterion for major transit capital expenditures.

Since the cost per new rider test differs markedly from the net present value criterion, we [the Project 2-17(1) team] used data provided in the project report to estimate the net present values implied in the forecasts and assumptions. Table 3 provides the net benefit streams developed in our counter-factual analysis for a 17 year period--the period over which forecasts were presented in the project report. Benefits represent the monetary value of time savings (reduced congestion) and fuel savings that result from each alternative.

Table 4 compares the cost per new rider developed under the UMTA guidelines with the net present values estimated in the counter-factual analysis outlined above. The comparison indicates that none of the options considered can be justified on economic criteria. Moreover, while the cost per new rider criterion ranks light rail transit highest (i.e. it displays the lowest cost per new rider) the net present value test ranks that option third, preceded by "Super TSM" and Express Bus #2.

The analysis outlined above indicates two major distortions in the analytic and decision-making process stem from the failure to adopt an economic criterion. The first is that cost-effectiveness tests provide no indication of whether investment alternatives contribute positive net benefits to the economy. In the example above, none of the alternatives appear to yield gains to the economy sufficient to justify their capital and operating costs--indeed, the negative net present values indicate that each option takes more out of the economy than it puts back in. Yet the cost per new rider criterion reveals no information for decision-makers with which they can examine that fundamental economic question.

Second, even where a policy decision has been made to make transit investments, the cost per new rider test misinforms the decision-maker regarding the lowest-cost, most economically effective approach. The estimates in Table 4 indicate that, using the same assumptions and forecasts presented in the original project appraisal, the express bus option was clearly the superior approach from an economic point of point view. In fact, the net present value is very nearly positive at the discount rate of 5.75 percent. Yet the cost per new rider test clearly favors the light rail option, when its contribution to the economy is actually a negative $8.6 million. At the higher discount rate of 10 percent, losses under the light rail option are an estimated $18.6 million; 10 percent is the discount rate recommended by the federal Office of Management and Budget.

Although the net benefits in Table 3 were calculated to the year 2000, the time horizon selected in the original appraisal under the UMTA guidelines, the capital assets under consideration would in fact generate benefits well beyond that year. In particular, the light rail options, which generate higher costs in the early years, also generate benefits over the longer term in the form of avoided congestion and fuel savings.

Case 27: Local Port Project

This case illustrates the sensitivity of the net present value criterion to the proper application of Benefit-Cost Analysis procedures, which in turn hinges upon a sound understanding of the underlying economic objectives of net present value analysis.

The project in question was the proposed containerization of a local port. The original project appraisal used net present value as the acceptance criterion and concluded that the project was worthwhile with an estimated NPV of just $9.8 million. Counter-factual sensitivity tests on alternative discount rates (conducted as in the preparation of this Part) indicates that the net present value remains positive under a wide range of discount rate assumptions.

However, in establishing the Base Case for the analysis, the original appraisal assumed that no other containerport facilities would be built that might be potential competitors to the proposed facility. Yet, within 50 miles, a new containerport had recently been installed. Since the benefit methodology in the report based benefit estimates on ground access time savings required to get goods to and from the containerport, and assumed that shippers would choose the containerport with least ground access

Table 3: Net Present Value and Net Benefit Streams of Transit Alternatives to 2000
(Millions of 1983$, 5.75% discount)

	TSM Baseline	TSM Super	Express Bus #1	Express Bus #2	LRT #1	LRT #2
NPV	0.00	-5.66	-16.35	-0.27	-46.85	-8.55
1984	0.00	0.00	0.00	0.00	-8.30	-8.30
1985	0.00	-0.29	-0.03	0.12	-0.65	-0.35
1986	0.00	-0.75	-6.45	-3.63	-22.95	-12.30
1987	0.00	-0.30	-6.49	-3.13	-43.72	-22.59
1988	0.00	-0.17	-3.34	-0.60	-27.59	-9.57
1989	0.00	-0.47	-1.20	-0.38	-2.53	1.60
1990	0.00	-0.79	-0.08	-0.49	3.24	2.31
1991	0.00	-0.41	-0.28	0.45	4.49	3.77
1992	0.00	-0.31	-0.32	0.15	3.26	3.14
1993	0.00	-0.66	-0.37	0.70	2.94	3.22
1994	0.00	-0.49	-0.40	1.26	2.53	3.11
1995	0.00	-0.45	-0.44	1.25	7.26	6.13
1996	0.00	-0.84	-0.48	1.40	7.86	6.63
1997	0.00	-1.34	-0.52	1.16	17.51	16.18
1998	0.00	-0.83	-0.56	2.35	9.68	8.05
1999	0.00	-1.44	-0.63	1.87	11.09	9.55
2000	0.00	-0.61	-0.65	3.03	11.09	9.45
2001						
2002						
2003						
2004						
2005						
2006						
2007						
2008						
2009						
2010						
2011						
2012						
2013						
2014						

TSM: Transportation System Management
NPV: Net Present Value
LRT: Light Rail Transit

Table 4: Ranking Alternatives with Different Cost Effectiveness Indices

Alternative	UMTA Cost Per New Ride	NPV (Millions)
Super TSM	$3.71	($5.60)
Express Bus #1	$18.18	($16.40)
Express Bus #2	$3.12	($0.30)
LRT #1	$5.86	($46.90)
LRT #2	$2.87	($8.60)

NPV: Net Present Value
UMTA: Urban Mass Transportation Administration
TSM: Transportation System Management
LRT: Light Rail Transit

requirements, the presence of another nearby containerport would reduce the usage, and consequently the benefits of the proposed containerport.

Our recalculation of benefits assuming that the nearby port would capture all traffic that could access the alternative port more cheaply than the proposed port results in a lowering of the $9.8 million net benefit estimate to a negative $25 million. Even with a lower (5.75 percent) discount rate, the net benefits are still negative at ($5.4) million.

Although motivation is difficult to ascertain post hoc it is apparent that the containerport project was viewed as a "good thing" for the local community regardless of the outcome of net present value analysis. Employment in the construction phase and on-going job creation were considered worthy aspects of the project in their own right. The net present value test may thus have been conducted as a routine requirement (in order to obtain funding from the Corps of Engineers) rather than as a serious gauge of the project's worth. This particular attitude can be expected to diminish the value of net present value analysis since important yet subtle considerations, such as full Base Case development and sensitivity testing, are less likely to be conducted.

CHAPTER 11

APPLICATION OF TECHNICAL PROCEDURES

This Chapter summarizes the evaluation of practitioners' use of technical procedure, using the evaluation criteria developed in Part I to guide the analysis.

Focusing on the case projects whose objectives emphasize productivity, growth and economic welfare, we have conducted an evaluation to ascertain whether impacts are estimated in accordance with the procedures of economic assessment that measure the prospective achievement of these objectives.

DESIGN OF THE BASE CASE

Evaluation Criteria

Measurement of the expected productivity, growth and welfare implications of investment options requires a baseline, a basis for comparison. Properly defining the basis for comparison--called the "Base Case"--is no less critical to a valid economic evaluation than specifying the nature of the investment alternatives themselves.

A common feature of many economic evaluations is that, without the project in question, nothing will be done to improve the problem at hand or to benefit from opportunities for improved economic efficiency. If government does not construct a bridge, traffic will be unable to cross the river. If a new runway is not built, management will do nothing to improve the operation of the present airfield.

Clearly, the "nothing happens" Base Case is a fictional view of how governments and transportation systems behave in the absence of investment. Without a new runway at a congested airport, for example, management will seek out other, less expensive ways of improving operations, such as high-speed runway exits and innovative use of taxiways. To be sure, improvements in the absence of major new investments may not result in benefits as large as those expected from major investment alternatives. A high-speed exit from an existing runway will reduce congestion, but not by as much as an additional runway. But the assumption that nothing will be done to improve efficiency in the absence of a major investment is obviously unrealistic and thus invalid as a basis for economic evaluation.

Since some portion of the benefits obtainable from major new investments can be captured instead through innovation and sound management of the existing infrastructure, a "nothing happens" assumption in the Base Case has the affect of potentially exaggerating the benefits of major new investment. This in turn can deflect infrastructure managers and decision-makers alike from discovering measures to improve the efficiency of existing assets and thereby release infrastructure capital for other, more productive projects. The net result is that less value is gained by the economy from capital resources that are generally available for infrastructure investment.

Clearly then, the Base Case is more than a mere point of reference. It is a real option that may be characterized as a careful projection of how the infrastructure under consideration would develop in the absence of major new investment but with the guidance of sound and innovative management practices designed to get the most out of existing assets.

Obtaining maximum productivity from current systems can involve capital expenditures and their inclusion in the Base Case is perfectly valid. As well, technological and non-capital improvements may be available as means of avoiding more costly investment and are valid and important considerations in defining the Base Case.

The Base Case addresses both partial and general equilibrium criteria, as follows:

Partial Equilibrium Criteria

- o Alternative administrative measures. For example, congestion at a tunnel may be eliminated by either building an additional tunnel, or simply raising tolls on the existing tunnel. Assessment of a new runway must show the runway to be superior to raising fees; and

- o Alternative technologies to provide the same net effect. Changing truck regulations to allow larger trucks may reduce the need for road expansion (at the expense of higher road maintenance costs and safety).

General Equilibrium Concerns

- o Timing. Technology sensitive investments tend to decline in cost over time. A project may be of positive net value now, but be of higher net value if delayed. The correct criteria for implementation is when the decline in cost per year equals the lost benefits per year; and

- o Alternate technologies.

General Findings

The results of the evaluation in summary indicate that;

- o A total of 60 percent of all cases use a "nothing happens" scenario as their baseline rather than defining a productive Base Case;

- o A total of 14 percent take steps to define a meaningful Base Case, but fail properly to define productive Base Case scenarios;

- o A total of 13 percent correctly define productive Base Case scenarios, but used flawed benefit-cost techniques, thus diminishing the value of sound Base Case design; and

- o A total of 13% correctly define a productive Base Case and applied correct benefit-cost techniques.

Distortions from mis-specification of the Base Case appear in the form of exaggerated net benefits of major investment options since a certain proportion of the benefits attributed to such options can be obtained from lower cost productivity improvements to existing assets. This is not, however, an indication of over-investment; rather, it indicates that investment dollars are not being directed to the most desirable use from the viewpoint of productivity, growth and improved living standards.

Case Study Evaluation and Counter-factual Analysis

Case 8: Highway Project. The original project appraisal assessed investment alternatives in comparison with a "nothing happens" scenario. However, a Transportation System Management (TSM) alternative, which could have been incorporated in the baseline, was instead defined as a project option. To quote from the report:

> A "no-action" scenario provides a baseline against which the results of potential actions can be measured .... Under some conditions it is possible to substantially increase the capacity of a roadway or transportation corridor by improved management of the existing transportation system. Examples of such improvements include: reconstruction and rehabilitation; high occupancy vehicle lanes; signalization/signal timing optimization; and mass transit/fringe parking/ride sharing.

The logic outlined in the second part of the quotation provides the basis for one of several options, but all options are subsequently compared with a "nothing happens" baseline. Moreover, the management improvements cited are not included in the major investment scenarios. The net result is that benefits that are available from improving existing assets with management and TSM initiatives are attributed to much more costly expansion options, thereby diminishing the likelihood of a decision to make existing assets more productive in lieu of expansion.

A number of projects in the sample follow the pattern as that outlined above--a scenario is developed based on productivity improvements to existing assets but it is treated a separate option in relation to a "nothing happens" baseline rather than incorporated into a productive Base Case. The Primer guides practitioners and decision-makers in means of incorporating productivity improvements into the Base Case itself.

Case 35: State Highway Project

A study was conducted by a state highway authority to determine if widening one of the state's turnpikes from two to three lanes would make sound economic sense. The study concluded that the net present value of widening the highway was roughly $350 million (see Table 5).

The vast bulk of the benefits of this project come from time savings to the auto users that result from less congestion on the widened highway. Improvements could have been made to the following assumptions that drive the calculation of these benefits:

- o The Base Case alternative did not consider the possibility of raising tolls. Although the road is a toll road, a toll increase to ration low-priority users could realistically have been included in the Base Case. In particular, the discounts offered to regular peak-hour commuters undoubtedly overloaded the highway during the peak and could be removed in a Base Case scenario; and

- o A single traffic forecast was used to test both the base-case alternative and the widened highway alternative. In reality, an unwidened highway (the Base Case) would begin to build congestion which would increase the cost of driving and this in-turn would

Table 5: Net Present Value Calculations Using Study Assumptions (000s of 1988 $)

Year	Accident Benefits	Annual Time Savings	Increased Operating Costs	Construction Costs	Net Present Value	Cumulative Net Present Value
1988				$3,200	($3,200)	($3,200)
1989				$9,000	($8,571)	($11,771)
1990				$19,900	($18,050)	($29,821)
1991				$59,500	($51,398)	($81,220)
1992	$2,943	$5,751	$493	$20,200	($9,872)	($91,091)
1993	$3,491	$8,266	$507		$8,815	($82,277)
1994	$4,066	$11,130	$522		$10,950	($71,326)
1995	$4,932	$14,382	$537		$13,344	($57,982)
1996	$5,833	$18,064	$553		$15,800	($42,182)
1997	$6,775	$22,231	$569		$18,331	($23,851)
1998	$7,483	$27,498	$137		$21,391	($2,460)
1999	$8,343	$33,487	$33		$24,438	$21,978
2000	$9,227	$40,265	$8		$27,555	$49,533
2001	$9,688	$42,282	$9		$27,556	$77,088
2002	$10,173	$44,387	$9		$27,552	$104,640
2003	$10,681	$46,612	$10		$27,554	$132,194
2004	$11,215	$48,940	$10		$27,553	$159,748
2005	$11,776	$51,396	$11		$27,557	$187,304
2006	$12,635	$53,955	$11		$27,665	$214,969
2007	$12,983	$56,656	$12		$27,554	$242,523
2008	$13,632	$59,490	$12		$27,554	$270,077
2009	$14,314	$62,466	$13		$27,555	$297,632
2010	$15,030	$65,591	$13		$27,558	$325,188
2011	$15,781	$68,865	$14		$27,554	$352,742

discourage auto trips. Traffic would grow at a slower rate on the unwidened road, and therefore time savings from building the road would be less. Hence, it would have been prudent and correct to use two different forecasts for this road, one for the unwidened state and the other for the widened state.

Table 6 recalculates the net benefits of this project assuming that travel time spent on the unwidened road is 20% less than the predicted in the original analysis. This implies that not as much time would be lost since 20 percent less traffic would improve traffic flow. Table 6, assumes the combination of more congestion on the unwidened road (relative to the widened road) and higher tolls on the unwidened road would divert something less than 20% of the traffic flow, and reduces the net present value of the project by a factor of ten! As shown in Table 6, the project under these assumptions becomes economically questionable and further sensitivity analysis indicates that negative net present values are more likely than positive values.

Certain case studies (Cases 33 and 34 for example) correctly define a productive Base Case alternative, but use flawed benefit-cost techniques. Counter-factual analysis performed on Case 34 indicates that had a net present value test been applied, the ranking of the project alternatives would not have favored the selected alternative.

Table 6: Net Present Value Calculations Using Lower Base Case Travel Volumes
(000s of 1988$)

Year	Accident Benefits	Annual Time Savings	Increased Operating Costs	Construction Costs	Net Present Value	Cumulative Net Present Value
1988				$3,200	($3,200)	($3,200)
1989				$9,000	($8,571)	($11,771)
1990				$19,900	($18,050)	($29,821)
1991				$59,500	($51,398)	($81,220)
1992	$2,943	$0	$493	$20,200	($14,603)	($95,823)
1993	$3,491	$0	$507		$2,338	($93,485)
1994	$4,066	$0	$522		$2,645	($90,840)
1995	$4,932	$0	$537		$3,123	($87,717)
1996	$5,833	$0	$553		$3,574	($84,143)
1997	$6,775	$0	$569		$4,000	($80,142)
1998	$7,483	$0	$137		$4,510	($75,633)
1999	$8,343	$2,543	$33		$5,346	($69,287)
2000	$9,227	$6,348	$8		$8,668	($60,619)
2001	$9,688	$6,668	$9		$8,669	($51,950)
2002	$10,173	$6,994	$9		$8,666	($43,284)
2003	$10,681	$7,348	$10		$8,667	($34,617)
2004	$11,215	$7,714	$10		$8,667	($25,950)
2005	$11,776	$8,107	$11		$8,670	($17,280)
2006	$12,635	$8,502	$11		$8,778	($8,501)
2007	$12,983	$8,931	$12		$8,667	$166
2008	$13,632	$9,379	$12		$8,668	$8,834
2009	$14,314	$9,849	$13		$8,668	$17,502
2010	$15,030	$10,343	$13		$8,669	$26,172
2011	$15,781	$10,865	$14		$8,667	$34,838

Few projects correctly define a productive Base Case alternative and apply correct benefit-cost techniques. Case 7, an airport capacity analysis, and Case 6, a national aerospace plan, are cases that are correct on both counts. These cases constitute useful examples for the Primer.

Case 7: A National Air Project

Case 7 specifies a detailed productive Base Case against which all major investment scenarios are subsequently compared. Moreover, productivity improvements to existing assets are also included in the major investment scenarios; in this way, the economic contribution of the major investment options are isolated from that of the productivity improvements to existing assets.

The productive Base Case maximized the efficiency of existing airside facilities at the airport in question without major expansion, through minor infrastructure improvements, new air traffic technologies and procedures, and two minimum peak-period landing fee schedules.

PROJECT SCOPE AND CONSIDERATION OF INTERDEPENDENCIES

This criterion examines the adequacy of project appraisals in capturing interdependencies with other transportation investments.

Evaluation Criteria

Benefits and costs of one investment project may be affected by those generated by another. For example, the benefits of a new highway interchange might be greater if the highway is also widened. The scope of the Benefit-Cost Analysis exercise should be sufficient to allow consideration of all relevant strategic choices in transportation investment.

There are two general equilibrium criteria here-project complementarity and project substitutability, as follows:

- **Project complementarity.** Project assessments should account for the impact of other projects which have a positive impact on the benefits of the project under study; and

- **Project substitutability.** Assessment should account for other projects which can substitute for the one under study. For example, improved rail transit might reduce the need for bus facilities.

General Findings

The results of the evaluation in summary indicate that;

- Of all projects considered, 53% take interdependencies with other transportation investments into account, including project complementarity and project substitutability; and

- 47% fail to take into account probable interdependencies with other transportation investments.

Recalculation of the benefits in the counter-factual analysis of case studies indicates a significant reduction of net benefit estimates, from the positive to the negative range, as a result of considering interdependencies. This does not necessarily imply over-investment; it does indicate however that public capital dollars are not being directed to their best use from the viewpoint of the national economy.

Counter-factual Analysis

Case 27: Local Port Project

A local port authority completed a study to build a container terminal. Analysts evaluated one particular configuration and concluded that the net present value of the project was $9.8 million (see also analysis of Case 27 earlier).

The original analysis assumes that no other containerport facilities would be built that could compete with the proposed facility. Within 50 miles, however, a new containerport had recently been developed. Since the methodology in the report bases benefit estimates on ground access time savings required to get goods to and from the containerport, and assumes that shippers would choose the containerport with least ground access requirements, the presence of another nearby containerport would reduce the usage, and consequently the benefits of the proposed containerport.

A recalculation of benefits, assuming that the nearby port captures all traffic that could access the alternative port more cheaply than the proposed port, results in a lowering of the $9.8 million net benefit estimate to minus ($25) million. Even with a 5.75% discount rate, the net benefits were still negative at ($5.4) million.

Case 3: National Airport Project

As discussed earlier, Case 3 did not consider the runway option in the context of a potential new airport being considered for the region. In the appraisal conducted by practitioners in Case 3, there is no allowance for the possibility of a new airport concurrently being considered for the metropolitan area in question. The same body had commissioned an economic impact assessment (Case 4) of a new airport for the metropolitan area. Case 3 was, however, considered in isolation of Case 4.

Counter-factual analysis indicates that, considered together, the economic returns from a new runway could be substantially diminished by the timing of a new airport, particularly if the existing airport is to be closed upon commissioning of the new facility.

IDENTIFICATION OF BENEFITS AND COSTS

Evaluation Criteria

Evaluation in terms of this criterion seeks to determine whether all relevant categories of costs and benefits are identified in current practice. Examples of categories to be accounted for include:

- **Congestion costs imposed on other transportation systems.** Does a state highway shift congestion in a downtown core?

- **Scale economies/diseconomies outside of the actual transportation facility and its immediate users.** Increased traffic flow may result in urban growth and a shift in average costs for some industries in the city.

- **Passenger time savings.** Are these savings adequately quantified and expressed in monetary units when accounting for reduced or avoided congestion and delay?

- **Reduced inventory.**

- **Safety gains** in life and limb.

- **Benefits and costs to those outside the funding jurisdiction.**

- o Noise costs.

- o Water table/water shed impacts.

- o Wildlife impacts.

General Equilibrium Concerns

- o **Land use restrictions/enhancements of surrounding land.** This can be captured through property values, or through the additional expenses required to preserve existing uses.

- o **Utilization of excess capacity in other industries.** Of most concern are net increases in employment due to the elimination of structural unemployment in underemployed sectors of the economy.

- o **Impact of quality improvements.** The new project may change the underlying nature of the transportation service being provided. Existing users may place a higher value on the service because of the increase in quality of service. For example, a new highway which shortens distance between two points may provide benefits beyond the savings in operating costs to those using it. Trucking firms may now offer one-day service where before they could not. Business travellers may now be able to make trips in one day and spend more time with their families.

General Findings

Few of the case studies consider all relevant categories of benefits and costs, either in quantitative or qualitative terms. While virtually all cases consider environmental categories (e.g., noise, air pollution), it largely appears due to stiff requirements regarding Environmental Impact Statements. There are no parallel requirements for governing the analysis of economic impacts, the area that is typically the weakest in the cases examined. It should also be noted, however, that the treatment of environmental factors is typically presented in physical terms, with no attempt to assess the economic value of environmental costs and benefits.

The results of the evaluation in summary indicate that;

- o A minority-20 percent of all case studies-identified all relevant cost and benefit categories;

- o A total of 27 percent identified a majority (6 or more) of the 12 categories outlined above; and

- o Some 53% identified a minority (5 or less) of the costs and benefits identified above.

Case Study Evaluation and Counter-factual Analysis

Categories of costs and benefits most frequently omitted from project appraisals are:

- Congestion costs imposed on other transportation systems;
- Scale economies/diseconomies outside of the actual transportation facility and its immediate users;
- Passenger time savings;
- Reduced inventory (the equivalent of passenger time savings for freight);
- Benefits and costs to those outside the funding jurisdiction; and
- Utilization of excess capacity in other industries.

The failure to quantify congestion impacts must be underscored as a serious concern. A number of recent studies indicate that the costs of congestion are far greater than previously realized. Studies at Minneapolis-St. Paul and Vancouver International Airports conducted recently by Hickling indicate that the present day value of congestion over the next 20 years, if no new runway capacity is added, is in excess of $4 billion at each site. The failure to fully quantify the marginal social costs of congestion is very likely indeed to lead practitioners and decision-makers to ignore major opportunities for economic gains as a result of infrastructure investment.

Another shortcoming in current practice is a propensity to consider productivity gains for the public sector alone. A major Benefit-Cost Analysis of the National Airspace System Plan (Case 6) recognizes major productivity gains to the federal government from the reduced requirement for air traffic controllers with the advent of advanced automation. However, private industry might also gain from the more direct routings that in turn make deliveries of high value air freight more reliable and reduce inventory costs. While recognition of such benefits and methodologies to accommodate them are just now coming to light, systematic failure to recognize them in the past has almost certainly led practitioners and decision-makers to miss infrastructure investment possibilities and underestimate some of those that are identified.

Case 7: Airport Capacity Study

The sample included only one case that attempted to assign an economic (monetary) value to environmental costs and integrate this value into an overall assessment of net present value. Using Risk Analysis (see later) and a series of environmental cost models, Case 7-an examination of airport capacity options-found that noise costs associated with the construction and operation of an additional runway had an 80 percent probability of causing costs of $45 million (in present value) to 6,205 households.

TREATMENT OF DEMAND

Evaluation Criteria

The volume of benefits is driven by expected future demand. Key factors to be considered include:

Partial Equilibrium

- Economic and demographic conditions. Demand for transportation is driven by population and economic activity and relevant prices. Simple trend lines over time can be misleading, in particular since forecasts based on trends during high growth periods has led to large overestimates of future needs.

General Equilibrium Concerns

- **Feedback of improved infrastructure on demand ("generated traffic").** Reduced congestion or improved facilities will cause an increase in the demand that would not have otherwise been forecast. Demand that is generated through the addition of infrastructure capacity must be distinguished from demand that would arise under the Base Case since the economic value of infrastructure benefits is different for each category;

- **Price effects from elsewhere in the economy.** Prices of other goods and services will influence transport demand. For example, high oil prices will reduce most transport demand;

- **Technical change in infrastructure.** The investment project may embody technical improvements which may have an impact on demand;

- **Technical change in transportation using industries.** Changes in industry practice may influence the demand for transportation infrastructure. In particular, technical change in the transportation industry may be triggered by the investment project under consideration. For example, the elimination of congestion at an under-river tunnel will increase the reliability of transit times and permit some firms to implement just-in-time delivery practices; and

- **Technical changes elsewhere in the economy.** For example, the use of facsimile machines may reduce the demand for courier services.

General Findings

The results of the evaluation in summary indicate that;

- Only 13 percent develop forecasts that attempt to take most or all of the factors identified above into account;

- **Less than half (47 percent) develop forecasts based on an underlying assessment of economic and demographic factors; and**

- Fully 40 percent develop forecasts without taking into account any of the factors identified above in a focused or quantitative manner.

Serious implications stem from the failure in almost all appraisals to distinguish between demand forecasts under the Base Case and traffic that is only likely to materialize in response to major infrastructure investment. In most cases, a single "unconstrained" forecast, is assumed to exist for all options and any benefit or effectiveness tests are developed accordingly. However, in a congested system, the build-up in delay under the Base Case will, in most situations, discourage some portion of traffic. Failure to account for the impact of congestion on traffic in the Base Case means that the cost savings (benefits) attributed to major investment alternatives are exaggerated (since benefits are assumed to be occasioned by traffic that would actually not arise in the Base Case).

Where studies do recognize the prospect of diminished traffic growth as a result of congestion, the issue is typically discussed only in qualitative terms and only in the context of specifying the transportation problem at-hand. Thus appraisal reports will recognize that a congestion problem is likely to reduce traffic growth unless corrected; when conducting the economic analysis, however, traffic is assumed to grow at the same rate under all scenarios.

The exaggeration of benefits to generated traffic does not imply a risk of over-investment; it does, however, imply a risk of mis-directed investment dollars--a risk that capital is not being applied to the most worthwhile projects from the viewpoint of promoting productivity and growth.

Case Study Evaluation and Counter-factual Analysis

Case 35: State Highway Project

As discussed earlier, a single traffic forecast was used to test both a base-case alternative and a widened highway alternative. In reality, an unwidened highway (the Base Case) would incur mounting congestion; this in turn would increase the cost of driving and thus discourage auto trips. Traffic would grow at a slower rate on the unwidened road, and therefore time savings from building the road would be less. Hence, it would have been prudent and correct to use two different forecasts for this road, one for the unwidened state and the other for the widened state.

Table 6 recalculates the net benefits of this project assuming that travel time spent on the unwidened road is 20% less than the predicted in the original analysis. This implies that not as much time would be lost since 20 percent less traffic would improve traffic flow. Table 6 assumes the combination of more congestion on the unwidened road (relative to the widened road) and higher tolls on the unwidened road would divert something less than 20% of the traffic flow, and reduces the net present value of the project by a factor of ten! As shown in Table 6, the project under these assumptions becomes economically questionable and further sensitivity analysis indicates that negative net present values are more likely than positive values.

Case 7 Airport Capacity Project

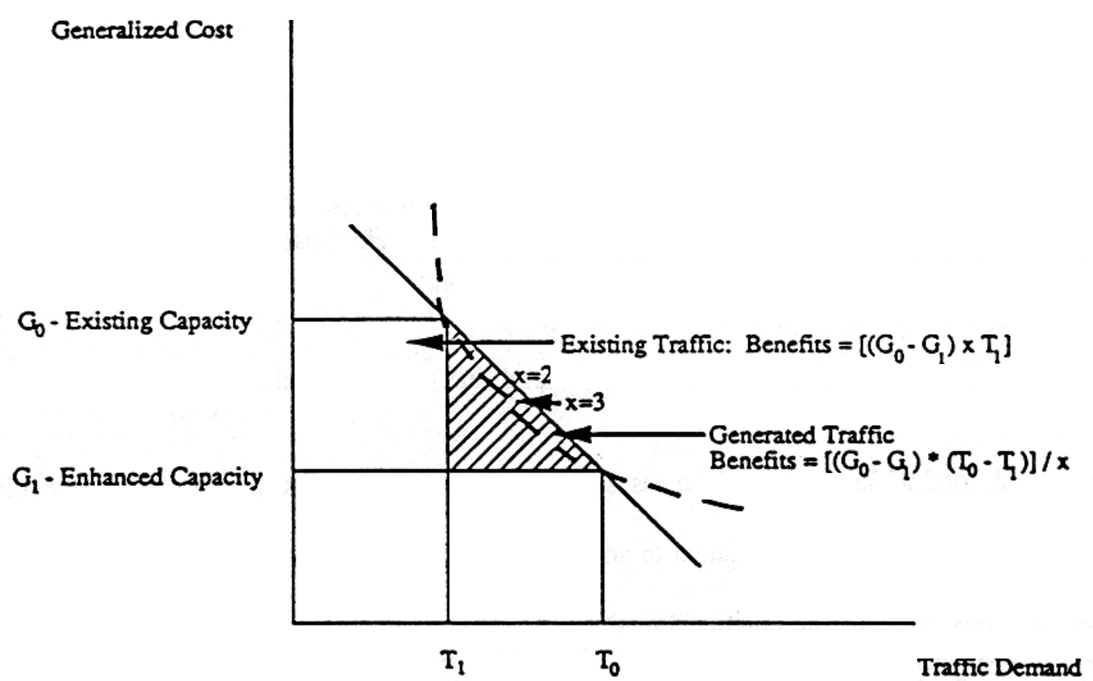
A key quotation from this case provides a very useful elucidation of the generated traffic concept. Case 7 represents the only example in the sample of 35 cases reviewed that undertakes to analyze generated traffic in detail. From Case 7 Report:

> The distinction between existing traffic and generated traffic is an important one in assigning economic value to aircraft and passenger time savings. Illustrated in Figure 4, a "demand curve" for air traffic means that a proportion of airport use in Strategy 2 (a

> new runway) would arise because of improved capacity and would not otherwise arise in the Base Case. Prior to the introduction of new capacity, this "generated traffic" was likely incurring less cost in its alternative activity than existing--Base Case--airport users; otherwise generated it would have been using the airport already. As shown in Figure 4, generated traffic thus occasions less economic gain as a result of airport development than existing users. . . . The extent to which benefits to generated traffic should be "marked down" depends, as shown, upon the shape of the demand curve. Drawing upon evidence in the economic literature, this analysis assumes the factor to lie between 2 and 3, reflecting a demand curve that lies between the linear and log-linear form within the range of demand under review.

Case 7 goes on to quantify both Base Case and generated traffic and apply the estimation rules outlined above in estimating the net present value of alternative investment options.

Figure 9: Benefits Generated to Traffic



Source: Case 7

Note: Generalized Cost denotes monetary cost plus time, valued in monetary units.

TREATMENT OF SECTORAL AND DISTRIBUTIONAL ISSUES

Sectoral transfers refer to the aim of shifting wealth or economic activity from one industry to another. When valued on its own, this goal would be chosen if one sector is favored for its own sake. This could result from a view of the sector as an engine of growth, from social values (such desire to sustain a traditional industry) or even from political clout.

The "distribution of income" commonly refers to the share of total output and income obtained by groups at different levels of income. Income distribution as an objective of policy indicates that a nation, or a sub-national geographic unit, may place a value on the fairness of the division of output, as well as its total value.

Evaluation Criteria

Part I concluded that the appropriate methodological approach in measuring the productivity and growth implications of investment while simultaneously recognizing distributional aims is to apply the net present value criterion but to restrict all projections of benefits, costs and discount rates to those in the sector or industry of interest.

The economic literature provides a number of techniques for measuring the distributional implications of transportation projects but few categorical criteria for judging when distribution is "optimized" from an economic point of view. The rigorous (though rarely used) approach applies judgemental weights to various sectors or income groups and then re-calculates the net present value accordingly. Any project whose weighted net present value is positive may be regarded as economically worthwhile and projects may be ranked according to income-weighted net present value.

We examined projects in the sample to determine if major sectoral and distributional issues were being adequately explored and disclosed. Distributional issues should be identified and discussed. They do not directly affect the calculation of overall net benefits and costs, but they are important for two reasons. First, distributional issues are inevitably of concern to decision-makers. Second, they identify affected stake-holders in ways than can reveal missing elements in the Benefit-Cost Analysis.

General Findings

Of the projects reviewed, roughly half examined sectoral and distributional issues, while the other half did not:

- o A total of 53 percent of the cases adequately examined sectoral and distributional issues.
- o A total of 47 percent failed to adequately treat sectoral and distributional issues.

The evaluation finds that most authorities do limit their evaluations to the regions under their authority but rarely are they targeted to particular industrial sectors. And it is rare to find the net present value criterion in use. Our review of the distributional analysis indicates that most practitioners measure employment and related multiplier impacts. A common approach is to examine the multiplier impacts of proposed investments and judge their suitability against implied national or local community standards. It is very rare indeed, however, to find examples of appraisals that attempt to determine whether employment and related multiplier impacts are incremental to the economy or redistributional (i.e. net gains in economic activity or jobs and income the value of which would be generated in the absence of the infrastructure in question). Thus studies of this sort rarely establish whether projects under review make a net contribution to productivity and economic growth in their region of interest.

Case Study Evaluation and Counter-factual Analysis

Again, a single case (Case 7) provides sound material for the Primer in the application of incremental multiplier analysis. There is no Case material, however, in the application of net present value analysis weighted to reflect distributional concerns. The Primer thus provides detailed guidance and case material from studies outside the sample considered here.

Case 7

The Case 7 report observes that the employment associated with existing or expanded infrastructure--including associated multiplier effects--can only be included in the calculation of economic benefits if it is "incremental"--that is, if it would not have accrued to the economy at-large in the absence of the project. The study notes that macro-economic activity will only be incremental if there is structural unemployment in the regional economy and if the next best use of the capital resources in question would create would create less macro-economic activity than airport development itself. The study provides a transferable model that puts these principles into practice.

TREATMENT OF TIMING AND DISCOUNTING

A key requirement of any investment analysis is an accounting for annual benefits and costs realized over an extended period, quite often at different rates. In order to compare alternative strategies on a common footing, all benefits and costs must be adjusted to a common baseline. Application of the techniques of discounted cash flow to public investment appraisal reveals the social and economic rate of return on infrastructure investment.

A failure to apply discounting techniques means that decision-makers cannot assess whether the rate of return on infrastructure projects makes the investment worthwhile--or whether the capital resources would add greater productivity, growth and welfare to the economy if directed to other uses.
More generally, the absence of discounting techniques will almost definitely result in the improper allocation of investment resources from the viewpoint of maximizing the economic contribution of infrastructure.

A related requirement of investment planning is the need to schedule investments in such a way as to maximize their potential contribution to productivity and growth. A project with an estimated net present value in the positive range can often be designed to yield an even greater NPV through adjustments to the timing/phasing of the project.

Evaluation Criteria

The following criteria guided the evaluation practitioners' application of timing and discounting principles:

Was the flow of costs and benefits over time correctly treated?

o Typically, transportation projects require investment now for benefits later. Because a dollar tomorrow is not worth as much as a dollar in hand today, costs and benefits in future years must be "discounted" to comparable worth today. The further in the future a benefit or cost is, the more it is discounted.

- o The accepted approach is to calculate the "present value" using an appropriate rate of interest called the "discount rate". For example, at a discount rate of 10%, $1.10 one year from now is worth only $1.00 today.

- o Was the period of time used to evaluate the project long enough--did it coincide with the longest living asset among the various scenarios under review?

- o Was account taken of any significant benefits still accruing at the end of this time period (i.e. "salvage value")?

Was the correct discount rate used?

- o Choice of the correct discount rate is important. If the rate is too high, we will wrongfully reject projects whose benefits are concentrated in the long run. If the rate is too low, we will accept projects whose benefits are too far in the future to justify investment today.

- o The correct discount rate for public projects has been a subject of continuing debate. However, there is consensus that it is less than the average rate of return to private capital, and more than the rate of interest implied by consumer saving behaviour. Some estimates have placed it around a real interest rate of 10% (real means without inflation).

Were alternative project start-dates tested in terms of net present value?

- o The contribution of an investment to the economy can be very sensitive to the start-date, the key factor being the timing of traffic growth. This is especially true for investments that draw progressively greater benefits as traffic grows. Since down stream benefits are worth less than early benefits (due to discounting) the net present value can be highly sensitive to alternative scheduling options.

Partial Equilibrium Concerns

- o The discount rate should be stated in "real" terms. This means that inflation should not be included.

- o The discount rate should be applied to "real" numbers. The effects of anticipated inflation should be removed before discounting. If the base year is 1986, then all future costs and benefits should be stated in 1986 dollars before discounting.

General Equilibrium Concerns

- o If appropriate, the discount rate should be adjusted for risk. "Risk" in this case is not the uncertainty of project costs or benefits. Instead, it is an adjustment made if the net benefits of the project are unusually highly correlated with the health of the economy. The correlation should be unusually high because all transportation projects will have net benefits correlated with the economy. This adjustment is rarely justified.

General Findings

The results of the evaluation in summary indicate that;

- The majority of cases (73 percent) do not apply discounting techniques at all;
- Of the 27 percent of cases that do apply discounting techniques, few look in sufficient depth at choosing the correct discount rate or subject the results to adequate sensitivity testing; and
- Only two of 35 cases specifically addressed the timing of infrastructure investment from an economic point of view.

If, nationally, almost three-quarters of all infrastructure project appraisals are made without the application of discounting techniques, the implication is that decisions are made without any information as to whether the rate of return on the investments is economically worthwhile (i.e. whether the projects generate productivity and growth-related benefits sufficient to outweigh the costs of achieving them, including the cost of capital). By analogy, it is as if corporations were to invest in plant and equipment without first examining the prospective rate of return. In the private sector, the evidence of such behavior would quickly become apparent in the financial performance of corporations; companies would be unable to service their debt or compensate equity holders and mounting losses would translate into systematic business failure. In the public sector, it is far less straightforward to establish whether projects are generating satisfactory social and economic returns. This in itself makes the application of proper measurement techniques critical as a basis for public investment.

The absence of discounting does not mean that nation has been over-investing. Indeed, the application of proper appraisal methods might well reveal a pattern of under-investment. Again, by analogy, the volume of capital investment undertaken by corporations will ultimately be decided through a continuous process of investment appraisal using discounted cash flow methodologies. The absence of such techniques in the public sector means that states, and the nation as whole, have no assurance that the selected projects, and their timing, have been in the interest of productivity, economic growth and the public welfare.

Case Study Evaluation and Counter-factual Analysis

Public Transit Projects

All transit project appraisals included in the sample used the Urban Mass Transportation Administration's guidelines for cost-effectiveness. As shown in earlier counter-factual analysis, the guidelines do not include a role for discounting; re-analyzing the data on a discounted cash flow basis changes both the revealed value of investment projects and change their relative performance (their "ranking").

Case 27: Local Port Project

The counter-factual analysis of Case 27 demonstrates the importance of conducting sensitivity analysis using alternative discount rates. As shown in Table 3, the present value of benefits assessed at 5.75 percent discount rate are $40 million compared to $9.8 million at an 8 percent rate. At $9.8 million, the project is very close to a negative economic performance.

Unless practitioners and decision-makers have a strong basis for using one discount rate over another, some sensitivity testing to small changes in the assumed rate is important in order to assess whether an estimated positive economic return on a project is robust to alternative discounting assumptions.

Case 7: Airport Capacity

Case 7 is one of two projects among all those evaluated that provides an unambiguous test of optimal project timing. The Case 7 report shows that the optimum year in which to commission an investment is the start-date that maximizes its net present value. The report goes on to prove that net present value can be shown to maximized when the benefits in the first year after commissioning a project, divided by the total capital and operating costs incurred to that date, including interest, is equal to the minimum desired rate of return. If this ratio-called the First-Year Benefit Ratio-is less than the discount rate, it means that delaying the project would increase its net present value. On the other hand, if the First-Year Benefit Ratio is less than the discount rate, the project may be said to be overdue.

Other measures of timing, such as the number of years needed to achieve break-even, provide useful information for decision-makers. The faster the pay-back, for example, the less reliant the project's return is upon relatively distant and uncertain forecasts. The Case 7 report shows that while this is obviously an attractive trait of any prospective investment, optimal timing requires finding the start-date that maximizes net present value.

TREATMENT OF RISK AND UNCERTAINTY

Evaluation Criteria

Many uncertainties enter into the conduct of a Benefit-Cost Analysis. Some of these are technical and involve forecasts about the future, while others reflect value judgements about economic and social factors and about the willingness of communities to bear more environmental cost or increased delay and less productivity, growth and economic development.

One thing about project appraisal is certain however: virtually every important forecast will be wrong to some degree, simply because the future is unknowable with complete certainty. Technical analysts and decision-makers should thus evaluate the sensitivity of analytic findings to variations in key assumptions that reasonably reflect the extent of uncertainty underlying them.

General Findings

Only 20% of the case studies in the sample examined the implications of uncertainty and risk in key assumptions.

In many of the cases examined, conclusions rest upon a large number of highly uncertain judgements and assumptions. Modern industry practice in such situations seeks to identify projects with lower rates of return and more certainty of success than potentially higher yield projects that also carry a higher degree of risk. Although techniques exist (see below), modern public sector practice is typically ill-equipped to deal with the comparative economic risks associated with its various investment choices.

Case Study Evaluation and Counter-factual Analysis

Although very few studies examine uncertainty and risk, there is proof, among the few studies examined that do so, that practitioners can supply decision-makers with profoundly useful analysis of the economic risks associated with alternative courses of action.

Two cases in particular show in depth how the techniques of Risk Analysis help provide important perspective on public investment by measuring the probability or "odds" that a net economic gain will actually materialize. This is accomplished by attaching ranges (probability distributions) to each assumption and judgement underlying the forecast. As well, the probabilities enable all assumptions to be varied simultaneously, providing a highly realistic simulation of reality in the sense that all assumptions do indeed veer from their expected outcomes at the same time. (This is in contrast to conventional sensitivity analysis in which assumptions are varied one at a time, quite unlike reality).

To improve confidence in the forecasts and help build community consensus around strategic infrastructure planning initiatives, one case applies a technique called RAP (the Risk Analysis Process). This is an open process that involves stakeholders in the community in establishing the options to be evaluated and in setting the probability ranges.

The net result of a risk analysis simulation is a quantitative statement of the probability associated with various forecast levels of passenger traffic, capacity, delay, benefits, costs, and, ultimately, net present value. For example, forecasts of aircraft delay in two of the cases using risk analysis do not provide single "point-estimate" forecasts but rather probability distributions of expected outcomes such that "there is an 80 percent risk that average delay in 1995 will exceed 11 minutes". There may also be a chance of very slight delays, say 10 percent, because of an uncertainty in demand estimates.

Risk analysis identifies the probability that the actual net present value of a given strategy will differ from its estimated value. This information is then used to develop a long-term development strategy that provides an economically efficient solution while minimizing the risk of either over-or under-investment. The approach appears to provide decision-makers and the community effected by decisions with very much the same kind of information used in major corporations to establish an investment plan that maximizes the return from invested capital and minimizes the risk of economic failure.

USE OF STANDARD VALUES

Evaluation Criteria

In assessing the sample studies, an assessment was made of the standard values being employed. We examined whether there was justifiable variation in the values employed for:

- The discount rate;
- The value of time savings; and,

- o The value of human life in safety studies.

Variation in these key values, which should be largely the same across the United States economy, would identify a need for common standards.

In addition, it is possible that the values typically chosen are too high or too low, affecting the aggregate level of investment in transportation infrastructure. Where there were any departures from normal standards, the review examined whether this was adequately explained and justified.

General Findings

For the most part, values in common use vary sharply from commonly accepted assumptions in the research literature. Re-analysis (counter-factuals) indicates that replacing original assumptions regarding the value of time and safety benefits with those in keeping with research can alter conclusions. Typically projects that were reported to yield positive gains for the economy are found to offer negative returns when standard values are used.

A common concern with Benefit-Cost Analysis and related techniques is that "It can be made to say anything, just by changing the assumptions." Although this is indeed the case, the problem stems not from vagaries in technique but from a lack of discipline in the valuation of key assumptions. Standardization represents an important requirement and the Primer begins the process of institutionalizing and thus stabilizing the use of discount rates, values of time and safety benefits.

CHAPTER 12

GENERAL EQUILIBRIUM IMPACTS

Part I of this report concludes that conventional Benefit-Cost Analysis has not yet incorporated measures of the private productivity payoffs associated with increased reliability, the facilitation of structural change in industry, economies of scale and other benefits to industry that return to the economy in the form of public benefits.

It is therefore no surprise that the evaluation of current practice finds that such impacts are not measured. The analysis required to identify and quantify, (at least initially) the scope of these impacts are incorporated in the Primer and done so in a manner readily accessible for application by practitioners and decision-makers.

Although the evaluation does not provide case material in this area for use in the Primer, a recent contribution by Dr. David Quarmby in the Journal of Transport Economics and Policy (published by the London School of Economics) is significant and developed into a hypothetical case for the Primer. Dr. Quarmby developed the first estimates of the value of transportation time savings in the 1960s and managed London Transport in the 1970s. In the early 1980s, he left the public sector to become Vice President of Logistics and Transportation for Sainsbury's, Britain's largest supermarket wholesale and retail enterprise.

Quarmby doubts whether current methods of Benefit-Cost Analysis fully account for the benefits of network improvements which often forge improved structural changes in distribution systems. He believes that the full benefits that flow into the private sector (and generate private capital inflows) from public sector infrastructure project investments are not being captured by traditional techniques, no matter how current their use. Quarmby develops case studies indicating that benefits to commercial vehicles of road improvements, calculated as straight time savings (the conventional analysis), will tend to underestimate the true "business potential" gains in productivity to the private sector by some 30 to 50 per cent.

What implications can be drawn from the absence of general equilibrium impacts in current appraisal practice when viewed in the context of the general findings of the overall evaluation? The evaluation in previous Chapters indicates a very small likelihood that capital resources available for infrastructure are being directed to the mix of projects and programs that would generate maximum returns to the economy. No conclusions can be drawn from the evaluation as to whether the **level** of investment is too high or too low. Rather, the results indicate that, without major improvements in appraisal practice, the correct level of investment cannot and will not be determined.

In itself, however, the absence of a major class of benefits-the so-called general equilibrium impacts-would suggest a pattern of under-investment in infrastructure in the United States. This conclusion would only be invalid if failures in appraisal practice have themselves led to sharp over-investment. This seems unlikely however given what we now understand about the very large economic costs associated today's levels of congestion and the very significant **net** benefits associated with their resolution through infrastructure investment.

CHAPTER 13

CONCLUSIONS ON 1990 SURVEY OF CURRENT PRACTICE

Based upon a sample of 35 projects, Part II examines the extent to which the three requirements listed above are met in practice. The results are summarized below.

Choice of Objectives

To ensure that infrastructure investment makes a net contribution to productivity and economic growth, managers and decision-makers need to aim for projects and programs whose projected economic benefits (expressed in terms of their present-day value) can be expected to exceed the present-day value of their associated economic costs (i.e. the "net present value" must be positive). To ensure that the rate of return on each project is high enough to justify the corresponding sacrifice of current consumption, present-day values are computed using a "social" discount rate-a rate that reflects the social opportunity cost of capital. Thus, rather than accepting all projects that promise a gain in productivity and growth (which would equate to the approval of any project with a positive rate of return), this approach ensures that the economic gains associated with productivity improvements and economic growth outweigh the full range of economic costs (including environment and congestion costs) of achieving them. In short, the appropriate test is one that views productivity and growth within the context of overall economic well-being.

From the viewpoint of productivity and growth, the choice of objectives and related evaluation methodology outlined above should be given primacy over the application of employment multiplier methodologies, economic impact techniques and input-output analysis. These techniques measure the way in which infrastructure projects and programs affect the distribution of economic activity, and will thus be of importance to various aspects of economic decision-making, but they do not indicate whether or not new investments are likely to foster improved productivity and economic growth.

The approach summarized above is consistent with that recommended by the American Association of State Highway and Transportation Officials (AASHTO)[2] and techniques developed by the Federal Highway Administration (the Highway Investment Analysis Package-HIAP, in particular). The AASHTO Manual and HIAP both focus on reduced transportation costs (including both operating costs and the value of time savings) as the principal economic benefit of transportation infrastructure improvements. As discussed later, however, neither recognize nor attempt to measure economic benefits stemming from the adoption by industry of more efficient inventory and other logistic improvements.

Based upon the evaluation of current practice, summarized in Figure 11, evaluations in the field rarely adopt objectives and related methodologies that reflect the objective of enhanced productivity and economic growth. More than half the projects examined focus exclusively upon the likelihood that infrastructure improvements or additions will attract additional employment or industrial activity to a region. While regional expansion may be promoted under this approach, such growth may result from geographic redistribution; there is no knowing whether overall economic gains from the investment exceed the investment cost of achieving them.

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2 American Association of State Highway and Transportation Officials, A Manual on User Benefit Analysis of Highway and Bus-Transit Improvements, 1977

Only 13 percent of the projects examined indicated productivity and growth to be primary objectives. Some 40 percent of the projects make reference to productivity and economic growth as an objective, but relegate these aims to secondary or lesser status, usually in favor of objectives that focus on the attraction of employment and industrial activity to an area.

As shown in Figure 10, only about a third of the projects examined use the net present value criterion as a basis for evaluation and only five percent use adequate discounting techniques and properly justified discount rates. The failure to adopt the net present value test means that decision-makers cannot size up the performance of infrastructure projects in terms of their prospective net contribution to productivity, growth and economic well-being.

Application of Technical Principles

The evaluation, summarized in Figure 11, exposed a wide range of weaknesses in the application of technical procedures. Many are consequences of not selecting productivity, growth and economic well-being as the objective, and net present value as the acceptance criterion. Others represent shortcomings in current practice for the pursuit of these goals.

- **Design of the Base Case.** Only if improvements yield net economic gains in excess of those available from efficiency improvements to existing infrastructure can such investments be considered economically desirable. The Base Case provides a control and assists in maximizing national economic welfare. Most project appraisals do not establish, (or do not develop) an adequate baseline against which to assess economic improvements. Projects in general either failed to select and define a productive Base Case alternative or inadequately designed the Base Case. Some developed an improved transportation system management alternative--but relied on a "no action" or a "nothing happens" baseline as a basis for comparison.

- **Treatment of Timing and Discounting.** A key characteristic of any investment analysis is the need to account for the annual growth and decline of benefits and costs realized over an extended period. In order to compare alternative strategies on a common footing all benefits and costs must be adjusted to a common baseline. The appropriate adjustment procedure is to discount all future benefits and costs to their present-day values. Most projects failed to express costs and benefits over time or to adequately treat timing and discounting. They failed to express costs and benefits on an annual basis over the life-cycle of the project--for example, over a 25 or 30 year period. Analysis is typically not undertaken to determine the most appropriate timing or start year of projects.

- **Treatment of Demand.** Most projects failed to develop different forecasts for each alternative under study. Most projects tended to use a general economic forecast developed by an outside organization for some other purpose and to apply this general forecast to each of the alternatives under study. Studies rarely make the important distinction between Base Case and generated demand.

FIGURE 10

SURVEY OF CURRENT PRACTICE IN THE CHOICE OF INFRASTRUCTURE APPRAISAL METHODOLOGIES IN RELATION TO THE ECONOMY

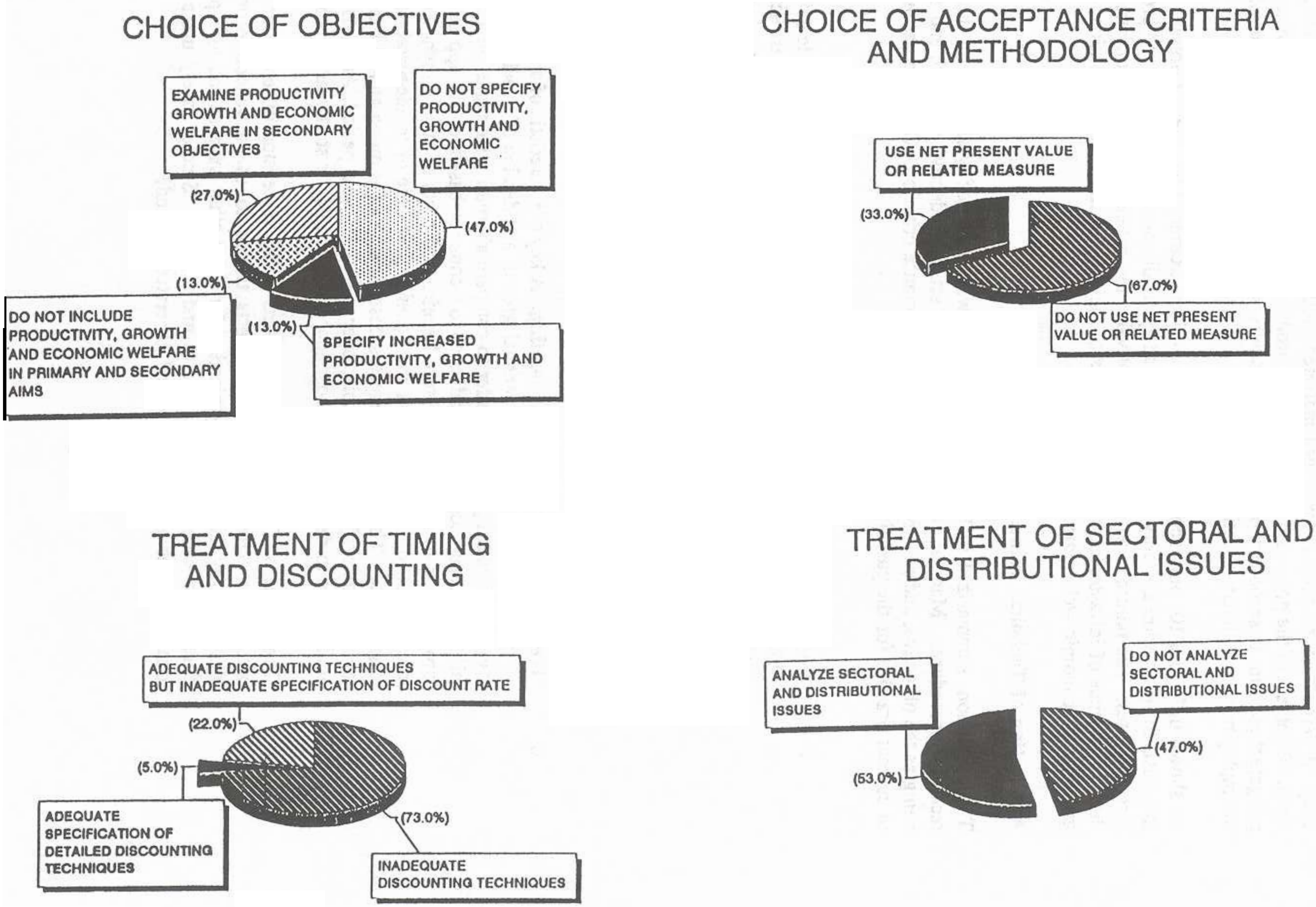
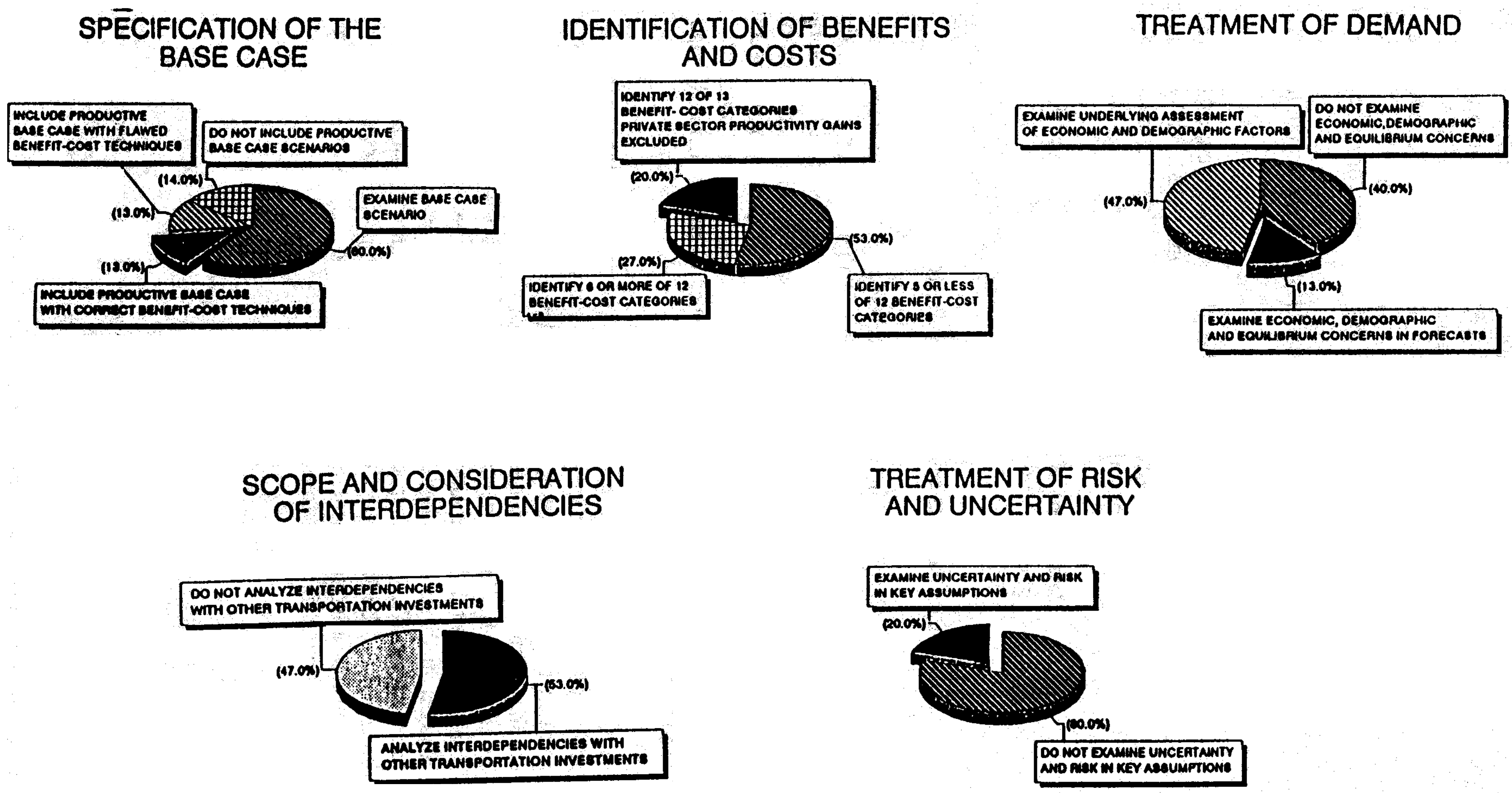


FIGURE 11

SURVEY OF CURRENT PRACTICE IN THE APPLICATION OF INFRASTRUCTURE APPRAISAL METHODOLOGIES IN RELATION TO THE ECONOMY



- o **Project Scope and Consideration of Interdependencies.** Most studies fail to account for the existence of other, interdependent projects. Failure to account for such interdependencies--the situation in half of the case studies considered--has serious implications for the choice of infrastructure alternatives. Recalculation of the benefits in the counter-factual analysis indicates significant lowering of net benefit estimates, from positive to negative, as a result of considering interdependencies.

- o **Use of Standard Values.** Most projects do not undertake an analysis on the sensitivity of their assumptions.

- o **Identification of Benefits and Costs.** Few of the case studies considered the major categories of economic benefits and costs. While larger projects (over $0.5 billion) do identify environmental impacts in physical units, few studies examine the economic implications of these impacts in relation to other costs and benefits.

- o **Treatment of Risk and Uncertainty.** Issues related to risk and uncertainty were largely ignored in the case studies.

Measurement of Benefits from Industry Restructuring

Firms are constantly examining the transportation system for opportunities to reduce company inventory costs and other overheads through changes in their production logistics, methods and technologies,[3]: these are efficiencies that translate into benefits to the economy at-large. The Input-Output Analysis framework assumes "fixed production technology" (i.e. constant input-output coefficients) and thus fails to anticipate the advent of such efficiencies in response to prospective projects. The Benefit-Cost Analysis framework for public projects focuses on gains in efficiency through reduced transportation costs, but fails to examine efficiencies obtained by private firms through changes in production logistics and technology.

In light of the above findings, the evaluation reveals that even in those limited cases where methodologies are rigorously and correctly applied, certain kinds of productivity gains are not measured in the assessment of infrastructure projects--namely, improvements in private sector productivity (i.e. the holding of smaller inventories stemming from better public infrastructure, agglomeration economies and so on. This finding is consistent with that of Part I which finds that current methods of Benefit-Cost Analysis do not fully account for the benefits of fast network improvements, which may include structural changes in distribution logistics. The failure of available methodologies to capture these (so-called "general equilibrium") impacts of projects confronts decision-makers with the risk of possible under-investment. The following Chapter presents the approach developed under Project 2-17(1) to incorporate infrastructure-induced benefits stemming from industry restructuring into the methodological techniques to be presented in the Primer.

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[3] Interview with Professor Martin Farris, Regents' Professor of Transportation and Logistics, Arizona State University, October 17, 1990.

SUPPLEMENT TO NCHRP REPORT 342

TECHNICAL REPORT

PART III

MEASURING THE PRODUCTIVITY OF TRANSPORTATION IMPACTS

CHAPTER 14

ACCOUNTING FOR PRIVATE SECTOR PRODUCTIVITY IMPACTS OF PUBLIC SECTOR INVESTMENT

Benefit-Cost Analysis is the appropriate tool to guide public investment decisions. In the context of infrastructure investment, the scope of current practice of benefit-cost analysis is, however, insufficient.

The infrastructure improvement benefits that are quantified under current practice generally include immediate impacts on private sector costs but ignore the longer run impact on private sector productivity. Benefits, as commonly measured, constitute an underestimate of the "true" benefits of infrastructure improvement by ignoring the potential impact of private technological improvements enabled by the new infrastructure.

For example, road improvements will allow users to travel more quickly at less cost. This may in turn alter the trade-off between transportation costs and the costs of maintaining distribution points, leading firms to change their logistics and operations. Current benefits measurement will capture the immediate cost savings, but tend to ignore the long run benefits of logistical reorganization. They may also miss the impact of other technological changes enabled by the investment in road improvements.

Equally important, alternative investment options may be improperly ranked by ignoring their impacts on private sector productivity. Which of several road improvement options is the most worthwhile? A widened road may yield the highest immediate benefits. But a new road may enable more firms to take advantage of the flexibility of satellite location and dispatching technologies.

The desirability of accounting for private sector productivity impacts is heightened by two current considerations:

- States and the nation are concerned with improving national productivity and increasing international competitiveness.

- The low level of investment in public infrastructure in the last decade may mean there is significant pent-up demand by infrastructure users to alter their logistics and operations to meet changed patterns of demand and adopt new production and distribution technologies.

Current Benefit-Cost practice has not addressed this issue for the lack of a practical and convenient estimation methodology. Typically, private sector productivity impacts have been lumped together with other "general equilibrium" concerns and the measuring of ever elusive impact on land rents.

The methodology presented here offers an indicative approach to measuring the impact of infrastructure improvement on private sector productivity. Although the method represents a preliminary framework which is now being examined, improved and finalized under NCHRP Project 2-17(4), it will help practitioners conceptualize potential benefits and project designs that would not otherwise be recognized using conventional methods.

The methodology is developed in the context of logistical and technological improvements by firms as they adapt to improvements in highway networks, but it is equally applicable to any type of infrastructure improvement. Suggestions are also offered for the extension of the model to special cases.

Application of the model to Benefit-Cost Analysis of investment projects is expected to yield a more accurate appreciation of the benefits of the project, and a greater ability to discern between alternative investments.

This section will first elaborate on the problem of measuring private sector productivity, and then present a proposed methodology to meet the problem. The description of the methodology is followed by numerical examples, and suggestions for further improvements.

THE PROBLEM

We begin by contrasting current practice measurement of infrastructure-related benefits to the improvements anticipated by accounting for private sector productivity improvements.

Current Practice

The conventional approach to measuring benefits of infrastructure investment is to estimate the direct cost savings to current users, and add an additional allowance for the benefits of increased infrastructure use caused by the lowered costs. No allowance is made for private sector productivity gains from restructuring enabled by the investment. Such restructuring can include, for example, reduced inventories in exchange for greater use of transportation systems; reduced stocking points (depots and so on); and the adoption of more efficient production-line technologies (such as just-in-time inventory).

Figure 12 illustrates the conventional evaluation approach for road network improvements. Use of the road network is expressed in vehicle miles for this example, but any physical unit of use would be appropriate.[4]

Before the road network improvement, current use is VM_0 and the cost of operation to users is an average of C_0. Demand for road use (D) is a function of the cost of road use, expressed in cost per vehicle mile. This cost corresponds to a generalized cost since it includes time, fuel, wear, depreciation, etc., as well as delay costs due to congestion. The lower the cost of using the road network, the more it will be used.

Suppose the road network improvement is expected to reduce congestion, saving time, fuel, and depreciation. The reduced cost per vehicle mile is estimated to be at C_1. Because of the lower cost of using the roads, use expands to VM_1. In order to estimate VM_1 the sensitivity of road use to the lowered cost will usually be estimated from local historical information or from studies of similar conditions elsewhere. For example, past information of the reaction of road use to congestion can be used.

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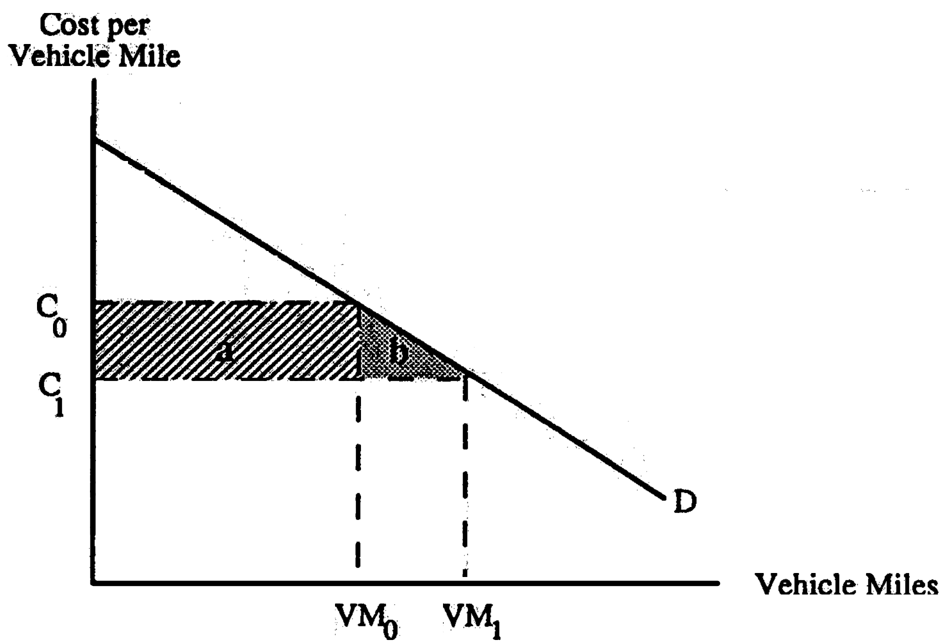
4 For example, average trips.

FIGURE 12 :

COMMON PRACTICE OF EVALUATING BENEFITS OF ROAD IMPROVEMENTS



The investment benefits consist of the shaded areas (a) and (b) in Figure 12.[5] Area (a) is the cost savings based on current road use, while area (b) is the net value of the increase in road use. Area (a) is estimated by multiplying the savings per vehicle mile by the total vehicle miles currently travelled (e.g. $1.00 per mile savings over 1 million vehicle miles is 1 million dollars.) Area (b) is usually approximated by the formula for a triangle, that is, one half the increase in vehicle in miles multiplied by the savings in vehicle miles.

In summary, the decision making authority usually begins with knowledge of current level of use of the infrastructure and current costs of using the infrastructure to users. Estimates are made of the cost reduction to users from infrastructure improvements and the resulting increased volume of use. The estimated benefits represent the immediate cost savings to users, both new and old.

Missing: Private Sector Productivity Impacts

The underlying assumption of the usual approach is that production and distribution technologies and patterns of infrastructure use will remain largely the same, except for expansion of road use as a result of the new investment.

Many potential impacts of infrastructure investment remain unaccounted for in the approach outlined above. What if firms reorganize their logistics and distribution networks as a result of the road improvements? What if the elimination of congestion improves the reliability of delivery schedules so that smaller and more frequent deliveries are made (in order to reduce inventory and handling costs)? What if the road improvements permit larger vehicles in some areas, or reduce packaging requirements?

In the extreme case, what if road improvements improve the efficiency of the road network to the point that there are fewer vehicle miles travelled? How can the benefits be measured then?

Solution: Quantifying the Shift in Demand for Infrastructure Use.

Typically, changes in distribution networks and other technological change enabled by investment have been considered "general equilibrium" impacts. Such benefits will ultimately emerge in the increased rents to well located land, plus increased income to other scarce factors of production.[6] Because identifying changes in land rents is a difficult task, measuring these benefits is commonly avoided.

An alternative way of measuring private sector productivity impacts is through the demand curve, namely the same analytic device used in the conventional approach (including that of the AASHTO Manual). It can be shown that the net benefit of private sector productivity improvements will be found in an increased area under the demand for infrastructure use.

For example, if the improved road network permits firms engaged in distribution activities (supermarkets,

5 Using willingness to pay as a standard of measurement.

6 Increased land rents is commonly cited, however it is more accurate to state that increased rents may accrue to any scarce factor of production involved in a transportation using industry. For example, those with entrepreneurial skills within the transportation industry may benefit.

for example) to lower their inventory overheads, their demand for infrastructure may increase. The lower inventory costs create additional potential profit, resulting in an increased willingness to pay for the use of infrastructure at any volume of use.[7] Stated differently, the firms increased willingness to pay stems from the net gain in profit arising from the substitution of transportation for inventory.

Figure 13 illustrates this example. The higher demand curve D' represents the shift in demand from the reduced inventory costs. The combined impact of lower operating costs per vehicle mile and the inventory savings results in volume of use VM_2. The benefits are given by the increase in surplus, areas (a+b+c). Area c is the impact of inventory reductions, and would likely have been missed by current practice.

Since any productivity increase in transportation-using industries creates an increased willingness/ability to pay, the net impact of any productivity improvement is captured by increases in the area under the demand curve. Therefore, the impact of private sector productivity improvements may be measured by quantifying shifts in the demand for public infrastructure. Quantifying shifts in the demand curve is the focus of the methodology presented below.

Shifts in demand in response to infrastructure investment must be considered common. It is part of a classic transportation decision making to trade-off transportation costs against inventory and handling costs. Inventory and handling costs can be reduced by more frequent deliveries of goods. Any significant change to road networks will alter the optimal trade-off for transport using firms, creating a shift in demand. According to Dr. Martin Farris, a professor of transportation and industry logistics at Arizona State University, the need to keep a constant watch on transportation infrastructure developments in order to identify profitable shifts in production and distribution logistics is a critical feature of the education and training of logistics managers at the Bachelor's and Master's level. As discussed below, this indicates that the information needed to anticipate productivity gains due to infrastructure improvements should be available through careful surveys and consultation with industry.

INFORMATION REQUIREMENTS OF THE METHODOLOGY

Practical measurement consists of two elements. First, the methodology must be defined in a way that is both theoretically sound, and relies only on available information. Second, a methodology must be developed to gather that information at reasonable cost.

This section develops a list of information requirements. The next section suggests how this information may be obtained.

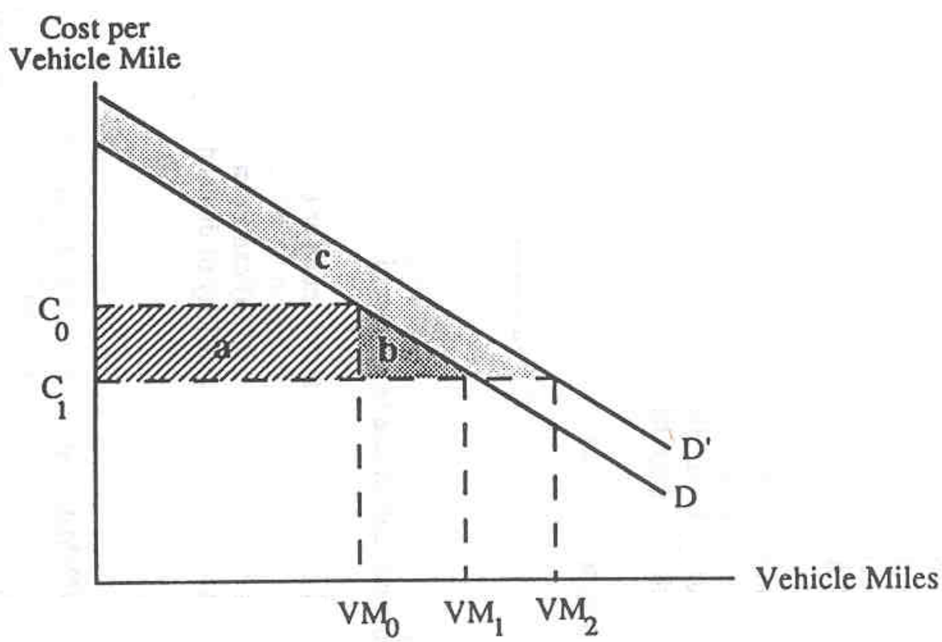
The Objectives of Measurement

The net benefits to infrastructure improvement, including private sector productivity gains, are defined by areas (a+b+c) in Figure 13.

[7] This profit need not actually be received by the transportation firms. In a competitive transport industry, the gains from the inventory savings will be passed on through lower prices to others. The eventual recipients will be the owners of scarce factors of production, such as land.

FIGURE 13

MISSING IMPACT OF PRODUCTIVITY GAINS OF ROAD IMPROVEMENTS



To estimate Figure 13 we need the sufficient information to establish:

- the before-investment demand curve for infrastructure use;
- the after-investment demand curve for infrastructure use; and
- the reduction in operating cost from the road improvements.

The text below summarizes the mathematical identities developed for the present purposes and identifies the information requirements for calculating them. A spreadsheet model has also been developed to enable those without a mathematical or economics background to make estimates. Readers not wishing to scrutinize the development of information requirements may wish to proceed to the discussion on data collection under "A PRACTICAL MEASUREMENT METHODOLOGY" further below.

Finding the Demand Curves

If we simplify estimation by using linear demand curves, then the before and after investment demand curves may be stated as straightforward relationships of available data.

The initial demand curve may be stated as

$$C = a - bVM \qquad (1)$$

where

C = Cost per unit of use (e.g. operating cost per vehicle mile).

VM = Level of use demanded (e.g. number of vehicle miles).

and (a) and (b) are constants.[8] Values of (a) and (b) can be calculated from current operating costs, current use of infrastructure and an estimated elasticity of demand. Specifically:

$$a = C_0 + (C_0/N) \qquad (1.1)$$

$$b = C_0/(N*VM_0) \qquad (1.2)$$

where VM_0 is the volume of use before road improvement (e.g. vehicle miles), C_0 is the operating cost before the road improvement (e.g. cost per vehicle mile), and N is the sensitivity of road use to operating costs (the "elasticity" of demand).

The innovation offered by the methodology presented in this paper is to show that the new demand curve, after infrastructure improvements, may also be estimated as:

$$C = a - bVM \qquad (2)$$

8 Point (a) is the intercept on the C axis, and (b) is the slope.

where (a) and (b) are changed to reflect changes in operating costs and in demand for transport:

$$a = [C_0 + (C_0/N)] / [1+DVM]$$

$$b = [C_0/(N*VM_0)] / [1+DVM]^2$$

where:

DVM = The percentage change in road use required by road using firms to provide their clients with the same volume of service as before the infrastructure investment. For example, if firms travelled 5,000 vehicle miles daily to deliver 10,000 tons of goods before the investment, and will travel 4,000 vehicle miles daily to deliver 10,000 tons, then DVM is negative 20% or (-0.20).

DVM may also be positive. If road improvements lead to fewer and larger points of distribution, the amount of road use for any volume of deliveries may increase as a result.

Necessary information for defining the demand curves in (1) and (2) is:

- Current volume of use of the road network, such as vehicle miles (VM_0).
- Current generalized operating costs per unit of road use, such as cost per vehicle mile (C_0).
- An estimate of the sensitivity of road network use to operating cost--the elasticity of demand (N).
- The percentage change in road network use under new firm logistics and operations, assuming the same volume of transportation service is being provided to customers as before the road improvements (DVM).

Operating Cost Savings

Cost savings will take two forms. There will be the customary direct cost savings in driving time, fuel, depreciation, etc. There will also be the net savings from changes in firm logistics and operations, or other technological change. The latter is the category that is often missed by current practice.

It is appropriate to include both types of savings as savings in operating costs. The volume of road network use is driven by the volume of business handled by transportation oriented firms. A reduction in overall costs of transportation services will result in the same increased volume of business, and consequent road use, regardless of its source. Therefore, the impact of a reduction in inventory costs on road volume will be the same as an equivalent reduction in operating costs per unit of road use.[9]

[9] The economists' "substitution effect" between road transport and inventory is accounted for in the shift of the demand curve, e.g. (DVM).

Therefore, we may define the reduction in operating costs ($DC) as

$$\$DC = \$DS + \$IS \tag{3}$$

where DS is the customary direct savings and IS is the indirect savings. For example, IS might be based on inventory savings divided by vehicle miles travelled.[10]

The necessary information therefore consists into: an estimate of cost savings per unit of physical use that includes an equivalent allowance for the indirect savings from improvements in logistics and operations and other technological change ($DC).

A PRACTICAL MEASUREMENT METHODOLOGY

We may summarize the information requirements to estimate net benefits of infrastructure investment in two blocks. First there are those items that are normally required in current Benefit-Cost practice, as illustrated in Figure 12. Drawing from the previous section, they are:

- Current volume of use of the road network, such as vehicle miles (VM_0);
- Current generalized operating costs per unit of road use, such as cost per vehicle mile (C_0); and
- An estimate of the sensitivity of road network use to operating cost--the elasticity of demand (N).

Figure 14 illustrates the role these three items of information play. They are used to estimate the current demand curve for infrastructure use.

Additional information required by the proposed methodology is necessary to estimate changes in the demand curve after road improvements:

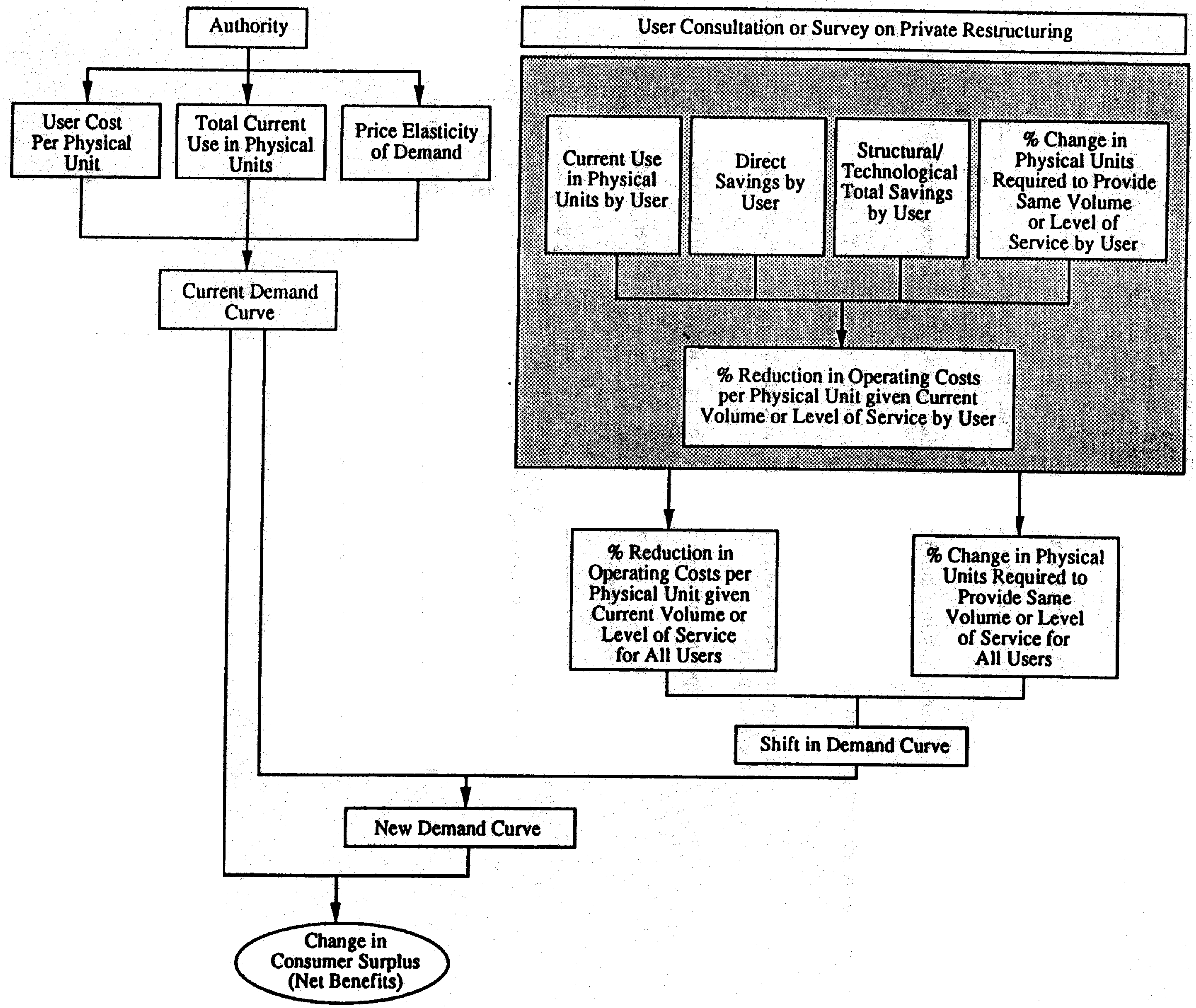
- The percentage change in road network use under new firm logistics and operations, assuming the same volume of transportation service is being provided to customers as before the road improvements (DVM).
- An estimate of cost savings per unit of physical use that includes an equivalent allowance for the indirect savings from improvements in logistics and operations and other technological change ($DC).

The latter two requirements are unique to the proposed method. The ensuing discussion will focus on them.

10 The astute reader will note that this approach assumes that inventory costs and other sources of savings will vary with road network use. While individual firms may regard inventory costs as part of fixed overhead, they will, on average, vary with overall volume of business handled by the industry. A lowering of overhead costs will have the same effect on total volume of road use as an equivalent lowering of the direct operating costs of vehicles.

FIGURE 14

ACCOUNTING FOR PRIVATE SECTOR PRODUCTIVITY GAINS



Evaluation of the practicality of information requirements should be made on two levels:

- Is the information something that an individual firm could reasonably answer?
- Is there a cost-effective way of gathering the information for an entire industry?

Questions for Individual Transportation Firms

The best and only source of information about how road improvements will affect transportation using firms is the firms themselves.

It is important in gathering information from firms that questions be reasonable and in terms that firms will be able to answer without excessive effort.

Answers to the following questions would answer the estimation needs of the model:

- How many vehicle miles (or other unit of choice) do vehicles operated by your firm travel annually?
- What proportion of these vehicle miles are travelled within the affected region?
- What is your total annual expenditure on drivers' wages, fuel, vehicle maintenance, etc? (List set of direct cost measures.)
- If these road improvements are implemented, and assuming that your volume of business stays at past levels:
  - What savings do you anticipate on the direct costs (listed previously)?
  - What changes in your operations, if any, would you undertake to take advantage of these improvements?
    - Are you likely to adopt inventory reductions?
    - Reduced number of stocking points?
    - Increased application of just-in-time inventory practices?
    - Changes in fleet composition?
    - A new production or distribution technology?
    - A new technology sooner than previously planned?
    - Other changes in operations?

- ° What further cost reductions do you anticipate from these changes in operations?
- ° What changes in vehicle miles (or other unit) do you anticipate as a result of these changes, given the same volume of business as you currently have?

Transportation intensive firms could reasonably be expected to answer these questions. Making trade-offs between stocking points and transport expenditure are a key feature of cost control in modern companies. The questions all focus on operational cost savings available to the firm, given its current volume of business. This reduces questions to an entirely technical level. Firms are not requested to speculate on how firm or industry demand changes. The basic requirement is limited to showing firms the new alternative plans and asking, in dollars and cents, how it will likely benefit them.

Answers to the above questions would be enough to determine the percentage change in operating cost and the percentage change in volume of use for the individual firm. The increase in distance travelled is a direct question. The effective decrease in cost per unit of infrastructure use would be computed using the following calculation.

The current operating cost (C_0) per physical unit is a straightforward division of firm direct transportation costs by vehicle miles travelled (or other unit measuring use).

The new effective operating cost (C_1) is previous cost per unit of road use (C_0) minus the direct savings in time, fuel, etc. (DS) per vehicle mile travelled, minus the indirect savings (IS) per unit of road use:

$$C_1 = C_0 - \$DS - \$IS/[VM_0*(1+DVM)] \qquad (4)$$

where

C_0 = The operating cost per unit of road use before road improvement. (Current firm transport costs divided by vehicle miles or other unit.)

$DS = The direct savings per unit of road use, such as driving time, fuel, depreciation, tire wear, etc. This may have been computed previously for all firms from knowledge of the nature of the road improvements, or may be taken from the firm's stated savings.

$IS = Total indirect savings from changes in operations and logistics, or other adaption to the road improvements.

VM_0 = The firm's current use of the road network, expressed in a vehicle miles or other unit.

DVM = The percentage increase in the firm's use of the road network resulting from its operational improvements, and assuming it continues to serve the same volume of business as before.

Note that the indirect savings ($IS) are divided by the vehicle miles travelled after the road improvements [$VM_0*(1+DVM)$]).

The calculation expressed by (4) represents firm expectations of the reduction in cost caused by the road improvements, on a per unit of road use basis. Each element of the calculation is satisfied by one of the questions above.

Naturally, firms may be uncertain about some of their answers to these questions. They may wish to speak in ranges of possible impacts, or likelihoods of making changes. Methods for handling this uncertainty are discussed further below.

Developing Estimates For Total Benefits

To obtain total benefits of a road improvement, categories of transportation-using firms need to be established and representative responses gathered from each. Total benefits will be the benefits to each type of firm weighted by their respective numbers.

Figure 15 illustrates the general approach. Firms that, directly (with own-account transportation) or indirectly (with purchased transportation services) make use of the road network are consulted and the responses codified to estimate the average reduction in operating costs and increase in road use. The identities presented above are then applied to calculate the increase in the area under the demand curve, which represents the net benefits of the road improvements.

Cost-Effective Ways of Gathering Firm Information

We suggest three methods of gathering information from representative firms:

- Consultation;
- Survey; and
- Panel Sessions.

Consultation and surveys are the two most common methods of information gathering. Consultation with known transportation firms is the most inexpensive method, but is easily subject to bias. Broader survey efforts rectify bias, but are costly.

Structured panel sessions, with trained logistics managers from within firms, are to be preferred for most cases. Representative groups of transportation-using firms are gathered and asked, through a structured series of discussions, to estimate average values for their industry group. This process has the advantage of incorporating peer review of responses, challenge by panel organizers, and immediate feedback. It also involves potential beneficiaries (and opponents if so desired) directly in the quantitative evaluation of the benefits.

Panel sessions avoid the costs of conducting and processing surveys, while preserving objectivity and representation in the process.

Panel sessions also lend themselves well to assessing the degree of risk and uncertainty involved in estimated benefits. When combined with a technique called Monte Carlo simulation, they can provide a clear picture of both average expected benefits, and the true range of uncertainty in those benefits created by weakness in the underlying data.

ACCOUNTING FOR UNCERTAINTY USING RISK ANALYSIS

Risk Analysis, used in a specialized way,[11] is an example of what may be termed a "consultative Monte Carlo process". It employs panel sessions in combination with Monte Carlo analysis.

Monte Carlo analysis may be briefly explained through Figure 15. In the normal calculation of an estimate, a single set of input values is used to calculate an expected benefit. A Monte Carlo analysis recognizes that input values, such as the reduction in cost per vehicle mile, is uncertain.

Instead of being given a single value, each input is given an expected value and a range of uncertainty. A computer program uses this information to repeatedly select random input values and calculate expected benefits. After a sufficient number of repetitions, the computer will have generated a complete probability distribution of the benefits. From this probability distribution it will be possible to make statements like "the net benefits of this project are 90% likely to exceed $3 million, with our best estimate being $5 million."

The role of the panels of transport firm representatives is to set the ranges of uncertainty on inputs. The panel members are not required to have knowledge of statistics. They need only have sufficient knowledge of their own firms to state the likely range of impacts of the proposed improvements. For example, "We estimate that the effect of opening up corridor B would be to reduce our travel time by 10% to 20%, with our best guess being 17.5%". And, "we give a 20 percent probability to the adoption of just-in-time inventory one year after the road network improvement; a 50 percent probability within one year; and a 95 percent probability within three years."

Through a structured series of questions, panel members can provide a true assessment of their own level of uncertainty on logistics changes in response to infrastructure improvements, which in turn are incorporated into the benefits estimation to yield a realistic appreciation of the degree of uncertainty (or lack of uncertainty) about the net benefits of the proposed investment.

EXAMPLES OF APPLICATION: A ROAD NETWORK IMPROVEMENT

Project 2-17(1) has developed a computer program (for use with Lotus 1-2-3 and desk-top computers) to relieve practitioners of the computational procedures outlined above. The following cases are based upon the application of this software.

The first of two examples presented here is drawn from a timely 1989 article by D.A. Quarmby, "Developments in the Retail Market and their Effect on Freight Distribution."[12] Quarmby's article is interesting because the author is both a well-regarded transportation economist with many years of public sector experience and (currently) Vice-President of Logistics and Transportation for Sainsbury's, Britain's

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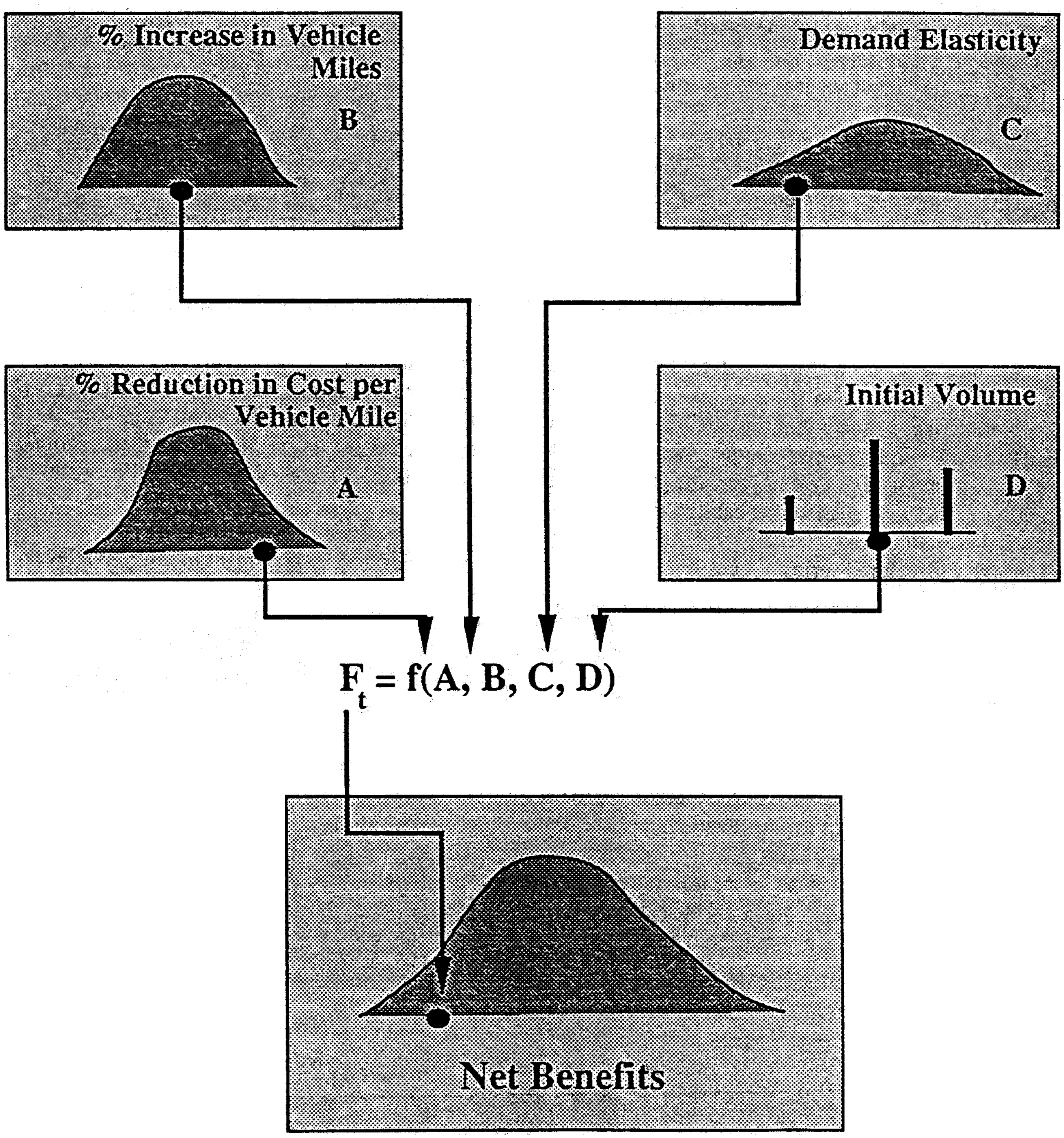
[11] The process outlined here is called the Risk Analysis Process (RAP), developed by the Hickling Corporation for assessing infrastructure impacts under conditions of uncertainty.

[12] Journal of Transport Economics and Policy, January, 1989.

FIGURE 15

MONTE CARLO SIMULATION: A WAY TO COMBINE PROBABILITIES



largest supermarket wholesale and retail enterprise.

The article addresses the same problem as discussed here, the overlooked benefits of logistical and operational improvements available to firms as a result of road network improvements.

Quarmby considers the impact of a road network improvement on food distribution in his firm alone (rather than the industry overall). The road improvements are seen to have two impacts. One is to reduce the driving time required for trips. The second, as result of the faster driving time, is to permit the firm to make a major structural change in logistics, namely to reduce the number of its depots from 6 to 5. The closure of depots requires an increase in the number of miles travelled of 9.5%, but the additional cost is outweighed by the savings from closing a depot. Savings in closing the depot come from reduced inventory holdings, and economies of scale in handling increased volumes of goods with one less depots.

Quarmby looks at the measurement of benefits to his firm in two ways. In Case A, he counts only the savings in driving time and associated costs, assuming that the structure of the firm's operations remains the same. In Case B, he considers the additional impact from the reduction in the number of depots.

Quarmby then provides the following table calculating benefits in terms of pence saved per case of goods handled. He also provides the information that total transportation costs are 20 pence per case.

Savings from Improvements in Road Network

	Per case handled
	p
Case A	
- Transport savings without restructuring	1.3
Case B	
- With restructuring:	
Marginal volume benefit	1.6
Stock saving	0.5
	2.1
Less extra transport cost	0.5
Total	1.6
- *Extra benefit* over transport savings	0.3 over 1.3p=23%

In Quarmby's example, the true benefits to the firms (including the benefits of restructuring) were 23 percent higher than those captured by conventional Benefit-Cost practice which would measure only the direct benefits from faster travel time.

As well as being an instructive example, Quarmby's article provides the kind of information that could reasonably be provided by transportation-intensive firms in the panel process outlined above. Quarmby's Case B calculation shows the net improvement to the firm, **including the impact of firm restructuring and assuming its volume of business remains the same.**

From this example, we can derive the information necessary to make a broader estimate of total benefits of the road network improvement to all firms. Taking Quarmby's example firm as representative, the average increase in vehicle miles travelled is estimated in the article to be 9.5%. Therefore (DVM = 0.095).

To obtain the percentage reduction in transport cost we may rewrite identity (4) as

$$C_1/C_0 = 1 - \$DS/C_0 - \$IS/[C_0*VM_0*(1+DVM)] \qquad (5)$$

The percent reduction in transport costs due to direct savings in time ($\$DS/C_0$) is the same as the proportion savings in total transportation costs per case (1.3/20) or 6.5%. In addition, the ratio of structural savings to total transport costs ($\$IS/(C_0*VM_0)$) is equal to the ratio of structural savings per case to transport cost per case (2.1/20 = 0.105). We may rewrite (5) as:

$$C_1/C_0 = 1 - 0.065 - 0.105/(1+0.095) = 0.84 \qquad (6)$$

Therefore operating costs per vehicle mile fell to 84% of their original value, or a 16% reduction.[13]

This information that vehicle miles increased 9.5% and operating costs decreased by 16% would normally be combined with overall market information on the elasticity of demand and cost and volume of use to establish net change in the area under the demand curve.

Since Quarmby's article does not extend from the firm to the total market, let us arbitrarily assume an elasticity of (N = 1.0), and an initial cost of 1,000 pence (10 pounds) per vehicle mile, and a volume of use of 10,000 vehicle miles annually.

Applying our demand relationships (1.1) and (1.2) yields an initial demand curve of

$$C = 2{,}000 - 0.1*VM \qquad (7)$$

and an after road improvement demand for road use of

$$C = 2{,}000/1.095 - (0.1/1.095^2)*VM = 1{,}826.5 - 0.0834*VM \qquad (8)$$

Under these values, the net surplus, established by the algorithm is 834,160 pence (8341.6

[13] Note that for Quarmby's firm the 16% reduction in per vehicle mile costs was partially offset by the 9.5% increase in vehicle miles for a net saving of 8% (1-1.095*.84 = .08) or 1.6 per case.

pounds). This may be compared to a surplus of 671,125 pence (6,711.3 pounds) if calculated according to the current practice of Benefit-Cost Analysis. Therefore, the common practice of ignoring restructuring by firms causes benefits to be underestimated by 24.3% in this example.

EXAMPLES OF APPLICATION: THE PARADISE PARKWAY

The Paradise Parkway concept is a fully access-controlled corridor improvement for Phoenix, Arizona. The Paradise corridor has been a component of the City of Phoenix Major Streets and Highway Plan and the Maricopa Association of Governments (MAG) Freeway/Expressway Plan since 1961 and 1974 respectively. The example has been developed here with the permission of the Arizona Department of Transportation but does not represent ADOT opinion. It should also be noted that the example represents a mix of actual data and hypothetical projections; more study would be needed to reflect the Paradise concept comprehensively.

Population and employment forecasts in the corridor study area indicate that the 1985 population will increase by 38% by year 2005 and 1985 employment will increase by 42% by year 2005. In addition, current traffic exceeds capacity of the existing street system at numerous locations. As a result, there appears to be a need for additional facilities to accommodate current and projected travel demand.

The present network is a "grid" system of major arterial streets at one-mile intervals, interspersed with minor arterials and collectors at half-mile spacing. Analysis of the present roadway system suggests that average daily traffic volumes regularly exceed desirable levels of service within the corridor and long delays due to extreme congestion are commonly observed at peak hour at several intersections.

In order to alleviate the above problems, the project would entail several network improvements that are expected to reduce:

- The number of intersections during peak;
- The number of roadway miles during peak as a proportion of total corridor street mileage;
- Travel times, especially for east-west trips;
- Daily vehicle miles of travel;
- Fuel consumption;
- Out-of-pocket operating costs;
- Air pollutant emissions; and
- Accidents.

The above list incorporates a number of potential cost savings that are recognized in conventional Benefit-Cost Analysis of road network improvements. However, to simplify the demonstration, we will set aside the questions of reduced air pollutants and accidents.

Suppose that the principal firms using the hood system are all identical. Each has 7 wholesaling depots distributed along the Paradise corridor which serve 10 supermarkets that are also distributed along the corridor. Each depot is located closer to the parkway than the supermarkets in order to make deliveries from depot to supermarket by transport firms as easy and efficient as possible.

A panel session is held of members of these firms, including logistics managers. Consensus is reached that the Paradise Parkway would have the following impacts on the average firm:

- If no restructuring is undertaken by the firms, the reduced driving time will reduce transportation costs by 5%.

- The need for one depot located at the west end of the corridor would be eliminated. Currently it is maintained and used for morning deliveries only since current westbound traffic flows are very heavy in the morning. The parkway would eliminate this congestion.

- Delivery times to depots are now more reliable. Deliveries to the depots will be increased from once daily to twice daily and the amount of inventory carried by depots will be reduced to a half a days supply. Net savings will result from the reduction in inventory and the reduction in spoilage of perishable goods.

- The percentage change in vehicle miles required to provide the same volume or level of service under the new arrangements is 8.5%.

- The combined savings from the closed depot, reduced overhead and reduced spoilage is equal to an additional 13% of current transportation costs.

Suppose, in addition, that the following information was known about industry use of the road network served by the Paradise parkway:

- The average operating cost per vehicle mile is $2.

- Current total vehicle miles, all firms, is estimated at 700,000 annually.

- The absolute value of the elasticity of vehicle miles with respect to operating costs is 1.3.

From the above information the change in road use is (DVM = 8.5%). The reduction in costs is (5% + 13%/1.085 = 17%). Applying this information to the algorithm yields an estimated net benefit to industry of $148,230. Ignoring the impacts of private sector restructuring would yield an estimate of only $72,275, an underestimate of 105.1%.

AREAS FOR RESEARCH

While operational, the methodology developed here should help focus future research into the relationship between transportation and the economy. Key studies would include:

- Retrospective case study investigations of the impacts of past network improvements on actual firms' decisions to change production and distribution logistics and operations. These would be quantified using the methods and computer programs developed above to give meaningful estimates of the productivity impacts of actual projects;

- Improved sampling techniques for the identification of representative firms for use in the process of estimating the productivity impacts of proposed network improvements;

- Development of a classification scheme of logistics and production/distribution technology improvements that can follow from transportation network investments. This scheme could follow from both the retrospective case studies suggested above and from direct case studies and interviews with firms. The classification scheme would be useful in a number of ways, including the conduct of panel sessions and the general search for productivity benefits associated with infrastructure improvements; and

- Development of a taxonomy of logistics and technology improvements classified according to the firms and industries in which such improvements can take place. This taxonomy would, in turn, be cross-classified with the infrastructure improvements that can help trigger such productivity impacts. This framework, developed on the basis of case studies and surveys (see above), would assist in the identification and quantification of potential productivity gains associated with prospective infrastructure improvements.

Among the possible technical improvements to the algorithms developed here are:

- Allowance for increasing returns to scale in transportation itself. The current method makes the conservative assumption that cost savings per unit of traffic volume remain constant as traffic expands. Cost savings are likely greater for transportation firms as volume increases. More deliveries within a given radius mean less dead-heading.

- Coverage of private sector productivity impacts in clients of transportation using firms. The current method only covers productivity improvements within the transportation-using firms themselves.

- Elaboration of cases to cover specific types of productivity gains.

- Generalization to cover non-linear demand curves. The current solution set uses linear demand curves as an approximation.

CHAPTER 15

CONCLUSIONS

It is evident from examination of current practice that there are significant gains available to the economy from improved practice in the evaluation of infrastructure investment. There exists a significant gap between current practice and correct practice, a gap which can easily be closed through improved awareness by practitioners and decision makers. Higher standards of living, productivity, and growth can be achieved by using the correct standards of measurement and the most practical and effective measurement techniques. A keener ability to measure and appreciate the benefits and costs of infrastructure investment will also help identify where there are needs for greater overall investment.

The methodology developed in this Part is an attempt at providing practitioners with the tools they need to establish the benefits of infrastructure investment that are beyond the reach of current practice of Benefit-Cost Analysis. In doing so, practitioners can actively contribute to a more efficient allocation of capital resources in the economy.

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APPENDIX A
BIBLIOGRAPHY AND REFERENCES

BIBLIOGRAPHY AND REFERENCES

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TRANSPORTATION ECONOMIC ANALYSIS

CASE STUDIES

EVALUATION FORM

James F. Hickling Management Consultants
June 22, 1990

AGENCY AND SAMPLE STUDY INFORMATION

Name of agency performing the economic evaluation: Case # ________________

Address of agency:

Name of Project:

Description of Project (use extra sheets if necessary):

____

____

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Point of Approval:

a. Appraisal in progress

b. Rejected

c. Approved, construction not started

d. Approved, construction complete

e. Other (explain) ____

What was the location of the project (i.e. local, regional or national)?

What was the mode of the project (i.e give the percent of highway, bridges, airports etc.)?

In dollars, what was the scale of the project?

What was the type of construction (i.e. new, repair, reconstruction etc)?

Conclusions of study (use additional sheets if necessary).

EVALUATION OF SAMPLE STUDIES

1. Evaluate whether the selected objectives were those that promoted the contribution of transportation infrastructure to productivity, growth and living standards (Use extra sheets if necessary).

2. Evaluate whether the adopted acceptance criterion and methodology was consistent with the selected objectives (use extra sheets if necessary).

2 (contd)

Definition of Base Case

3. Did the practitioners use a "nothing happens" Base Case or did they attempt to define a productive Base Case (covering all three elements of Base Case design)?

   a. "nothing happens"   b. Productive Base Case

4. (If the "nothing happens" Base Case was used) indicate the implications for the study findings using counter-factual analysis and selective sensitivity tests (use extra sheets if necessary).

Partial Equilibrium Concerns

5. Did the assessment address alternative administrative measures?

   a. Yes b. No

6. Did the assessment address alternative technologies that may have produced the same net effect?

   a. Yes b. No

General Equilibrium Concerns

7. When determining the timing for implementation of the investment, the correct criteria is when the decline in cost per year equals the lost benefits per year. Did the study use this criteria in determining the timing of implementation?

   a. Yes b. No

Scope of Study

8. Was the scope of the assessment sufficient to capture interdependency with other transportation investments?

   a. Yes b. No

General Equilibrium Concerns

9. Did the assessment account for the impact of other projects which have a positive impact on the benefits of the project understudy?

   a. Yes b. No

10. Did the assessment account for other projects which could be substituted for the one under study?

    a. Yes b. No

11. If the scope was insufficient, indicate the implications for the study findings using counterfactual analysis and selective sensitivity tests (use extra sheets if necessary).

____

____

____

____

11 (contd)

Cost and Benefit Concerns

12. Did the assessment address congestion costs imposed on other transportation systems?

    a. Yes b. No

13. Did the assessment address scale economies/diseconomies outside of the actual transportation facility and its immediate users? (i.e. increased traffic flow may result in urban growth and a lowering/raising of average costs for some industries in the city)

    a. Yes b. No

14. Did the assessment account for the benefit of passenger time savings?

    a. Yes b. No

15. Did the assessment account for the benefit of reduced inventory (i.e. the equivalent of passenger time savings for freight)?

    a. Yes b. No

16. Was the benefit to life and limb identified?

    a. Yes b. No

17. Were the benefits and costs to those outside the funding jurisdiction identified?

    a. Yes b. No

18. Were noise costs identified?

    a. Yes   b. No

19. Were water table/water shed impacts identified?

    a. Yes   b. No

20. Were wild-life impacts identified?

    a. Yes   b. No

General Equilibrium Concerns

21. Did the assessment address land use concerns? (i.e. Were the restrictions and the expenses to preserve existing uses identified)?

    a. Yes   b. No

22. Did the assessment address the concern of net increases in employment due to the elimination of structural unemployment in underemployed sectors of the economy?

    b. Yes   b. No

23. If (No) was answered for any of the questions 12-22 or if there were relevant costs or benefits not addressed, identify these and indicate the implications for the study findings using counter-factual analysis and selective sensitivity tests (use extra sheets if necessary).

23 (contd)

Forecasting of Transportation Demand

Partial Equilibrium Concerns

24. Did the forecasts of transportation demand account for economic and demographic conditions?

    a. Yes b. No

General Equilibrium Concerns

25. Did the forecasts address the feedback of improved infrastructure on demand (i.e. reduced congestion or improved facilities will cause an increase in demand)?

    a. Yes b. No

26. Did the forecasts account for price effects from elsewhere in the economy?

    a. Yes b. No

27. Did the forecasts account for technical change in infrastructure (i.e there may be a demand impact due to technical improvements over existing facilities)?

    a. Yes b. No

28. Did the forecasts account for possible technical change in industries using transportation (i.e. the investment project could trigger some firms to increase or reduce demand for transportation infrastructure)?

    a. Yes b. No

29. Did the forecasts account for technical changes elsewhere in the economy?

    a. Yes   b. No

30. If any relevant factors for forecasting transportation demand were not accounted for, list them and indicate the implications for the study findings using counter-factual analysis and selective sensitivity tests (use additional sheets if necessary).

Sectoral and Distribution Issues

31. Were major sectoral and distributional issues adequately explored and disclosed?

    a. Yes   b. No

32. (If No) list issues that should have been explored and indicate any implications for the study findings using counter-factual analysis and selective sensitivity analysis (use additional sheets if necessary).

32 (contd)

Flow of Costs and Benefits

Partial Equilibrium Concerns

33. Was the period of time used to evaluate the project long enough?

    a. Yes   b. No

34. List any significant benefits still accruing at the end of this time period that were not accounted for in this study (i.e. salvage value). Indicate any changes to the study findings if these benefits would have been addressed (use additional sheets if necessary).

Discount Rate

35. Was the discount rate less than the average rate of return to private capital, and more than the rate of interest implied by consumer saving behaviour?

    a. Yes   b. No

Partial Equilibrium Concerns

36. Was the discount rate stated in real terms (i.e. without inflation)?

    a. Yes   b. No

37. Was the discount rate applied to "real" numbers (i.e costs and benefits should be stated in base year dollars)?

    a. Yes   b. No

General Equilibrium Concerns

38. Was an adjustment made to the discount rate to account for the high correlation of net benefits of the project and the economy.

    a. Yes   b. No

39. If the discount rate was in error, specify the correct rate and the implications for the study findings in using this rate (use additional sheets if necessary).

39 (contd)

Net Present Value

40. Was net present value used as the decision criteria?

    a. Yes b. No

41. (If No) was the case established that the net present value could be expected to be positive?

    a. Yes b. No

42. (If No) indicate any implications for the study findings if net present value were used or in the case of just a cost-effectiveness study, a strong indication of a positive net present value was demonstrated (use additional sheets if necessary).

Risk and Uncertainty in Results

43. In the Benefit-Cost Analysis, exptain any weak points in the data and assumptions used (use additional sheets if necessary).

43 (contd)

44. Was the sensitivity of the overall conclusions tested to see if alternative assumptions or variations in the data affect the conclusions (i.e using Monte Carlo analysis or sensitivity analysis)?

    a. Yes b. No

45. Was there an assumption used that had a high risk of being invalid?

    a. Yes b. No

46. (If Yes) was the estimate for the net benefits reduced to account for this possibility?

    a. Yes b. No

47. Were any departures from the normal standards of practice adequately explained?

    a. Yes b. No

48. (If No) list these departures (use additional sheets if necessary).

48 (contd)

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APPENDIX C
DESCRIPTION OF EVALUATION CRITERIA

Text Box 1: GUIDELINES
IDENTIFYING THE BASE CASE IN INVESTMENT ANALYSIS

The "Nothing Happens" Base Case is a Basis for Comparing Alternatives

A common feature of many economic evaluations is that, without the project in question, nothing will be done to improve the problem at hand or to benefit from opportunities for improved economic efficiency. If government does not construct a bridge, traffic will be unable to cross the river. If a new runway is not built, management will do nothing to improve the operation of the present airfield.

Clearly, the "nothing happens" base case is a fictional view of how governments and transportation systems behave in the absence of investment. Without a new runway at a congested airport, for example, management will seek out other, less expensive ways of improving operations, such as high-speed runway exists and innovative use of taxiways. To be sure, improvements in the absence of major new investments may not result in benefits as large as those expected from major investment alternatives. A high-speed exit from an existing runway will reduce congestion, but not by as much as an additional runway. But the assumption that nothing will be done to improve efficiency in the absence of a major investment is obviously unrealistic and thus invalid as a basis for economic evaluation.

The "Nothing Happens" Baseline Exaggerates the Benefits of New Investment

Since some portion of the benefits obtainable from major new investments can be captured instead through innovation and sound management of the existing infrastructure, a "Nothing Happens" assumption in the base case has the affect of potentially exaggerating the need for major new investment. This in turn can deflect infrastructure managers and decision makers alike from seeking out and examining measures to improve the efficiency of existing assets.

The Base Case is a Real Option with Possible Spending Implications

Clearly then, the base case is more than a mere point of reference. It is a real option that may be characterised as a careful projection of how the existing infrastructure under consideration would develop in the absence of major new investment but with the guidance of sound and innovative management practices designed to get the most out of what we have.

Obtaining maximum productivity from current systems can involve capital expenditures and their inclusion in the base case is perfectly valid. In one example, a major $100 million investment alternative to the base case had to show benefits in excess of costs (that is, a positive net present value) after allowing for efficiency gains obtained from innovation in the base case. In another case, an airport included the capital cost of special high-speed exits and taxiway-runway link improvements in the base case of an economic evaluation major new runway proposals. The base case improvements were found to achieve fully 15 percent of the delay savings obtainable from a substantially more costly new runway.

The approach outlined above to developing the base case recognizes the management principle that the more efficiency we can seize from current assets, the less dependent we will be on major new capital investment, which, after all, is a scarce resource. The "something happens" base case ensures the most stringent and prudent test of the economic merit of new investment.

Technological and Non-Capital are Valid and Important Considerations in Defining the Base Case

In addition to moderate capital expenditures as a means of obtaining maximum productivity from existing assets, technological and non-capital improvements may be available as means of avoiding more costly investment.

- ° Was the correct baseline identified? (see Text Box 1 for example Primer guideline based upon this criterion)

  -- Measurements of the economic efficiency of prospective investment require a basis for comparison. Properly defining the basis for comparison -- called the "base case" -- is no less critical to a valid economic evaluation than specifying the nature of the investment alternatives themselves.

  Partial Equilibrium Concerns.

  -- Alternative administrative measures. For example a congestion at a tunnel may be eliminated by either building an additional tunnel, or simply raising tolls on the existing tunnel. Assessment of a new runway must show the runway to be superior to raising fees; and

  -- Alternative technologies to provide the same net effect. Changing truck regulations to allow larger trucks may reduce the need for road expansion (at the expense of higher road maintenance and safety).

  General Equilibrium Concerns.

  -- Timing. Technology sensitive investments tend to decline in cost over time. A project may be of positive value now, but be of higher net value if delayed. The correct criteria for implementation is when the decline in cost per year equals the lost benefits per year; and

  -- Alternate technologies.

° **Was the scope of the assessment sufficient to capture interdependency with other transportation investments?**

-- Benefits and costs of one investment project may be affected by another. For example, the benefits of a new highway interchange might be greater if the highway is also widened. The scope of Benefit-Cost Analysis exercise should be sufficient to allow consideration of all relevant strategic choices in transportation investment.

General Equilibrium Concerns:

-- Project complementarity. Assessment should account for the impact of other projects which have a positive impact on the benefits of the project understudy; and

-- Project substitutability. Assessment should account for other projects which can substitute for the one under study. For example, improved rail transit might reduce the need for bus facilities.

° **Were all relevant categories of cost and benefit identified?**

-- Examples of categories to be accounted for include:

- -- Congestion costs imposed on other transportation systems. Does a state highway increase/reduce congestion in a downtown core?; and
- -- Scale economies/diseconomies outside of the actual transportation facility and its immediate users. Increased traffic flow may result in urban growth and a lowering/raising of average costs for some industries in the city.
- -- Passenger time savings. This is often neglected when accounting for reduced or avoided congestion and delay;
- -- Reduced inventory (the equivalent of passenger time savings for freight);
- -- Safety gains in life and limb;
- -- Benefits and costs to those outside the funding jurisdiction;
- -- Noise costs;
- -- Water table/water shed impacts; and
- -- Wild-life impacts.

General Equilibrium Concerns:

- -- Land use. Restriction/enhancements of use of surrounding land. This is often captured through property values, or through the additional expenses required to preserve existing uses;
- -- Utilization excess capacity in other industries. The example of most concern is net increases in employment due to the elimination of structural unemployment in underemployed sectors of the economy;

-- Impact of quality improvements. The new project may change the underlying nature of the transportation service being provided. Existing users may place a higher value on the service because of the increase in quality. For example, a new highway which shortens distance between two points may provide benefits beyond the savings in operating costs to those using it. Trucking firms may now offer one-day service where before they could not. Business travellers may now be able to make trips in one day and spend more time with their families;

° **Did forecasts of transportation demand account for all relevant factors?**

-- Demand forecasts are the most uncertain and difficult task facing project evaluation. While costs of undertaking a project are relatively well known from past experience, the volume of benefits is driven by expected future demand. Factors which should be accounted for include:

Partial Equilibrium Concerns:

-- Economic and demographic conditions. Demand for transportation is driven by population and economic activity. Simple trend lines over time are not acceptable. Historically, taking time trends during high growth periods has lead to large overestimates of future needs.

General Equilibrium Concerns:

-- Feedback of Improved Infrastructure on Demand. Reduced congestion or improved facilities will cause an increase in the demand that would have otherwise being forecast;

-- Price effects from elsewhere in the economy. Prices of other goods and services will influence transport demand. For example, high oil prices will reduce most transport demand;

-- Technical change in infrastructure. The investment project may embody technical improvements over whatever it is expanding/replacing. These improvements may have an impact on demand;

-- Technical change in transportation using industries. Changes to ind ustry practice may increase/reduce demand for transportation infrastructure. In particular, technical change in the transportation industry may be triggered by the investment project under consideration. For example, the elimination of congestion at an under-river tunnel will increase the reliability of transit times and permit some firms to implement just-in-time delivery practices; and

- Technical changes elsewhere in the economy. For example, the use of fax machines may reduce the demand for courier services.

° **Were major sectoral and distributional issues adequately** explored **and disclosed?**

- Distributional issues should be identified and discussed. They do not directly affect the calculation of net benefits and costs, but they are important for two reasons. First, distributional issues are inevitably of concern to decision-makers. Second, they identify affected stake-holders in ways that can reveal missing elements in the Benefit-Cost Analysis.

° **Was the flow of costs and benefits over time correctly treated?**

- Typically, transportation projects require investment now for benefits later. Because a dollar tomorrow is not worth as much as a dollar in hand today, costs and benefits in future years must be "discounted" to comparable worth today. The farther in the future a benefit or cost is, the more it is discounted.

- The accepted approach is to calculate "present value" using an appropriate rate of interest called the "discount rate". For example, at a discount rate of 10%, $1.10 one year from now is worth only $1.00 today.

Partial Equilibrium Concerns

- Was the period of time used to evaluate the project long enough?;

- Was account taken of any significant benefits still accruing at the end of this time period (i.e. "salvage value").

- **Was the correct discount rate used?**
  - -- Choice of the correct discount rate is important. If the rate is too high, we will wrongfully reject projects whose benefits are concentrated in the long run. If the rate is too low, we will accept projects whose benefits are too far in the future to justify investment today;
  - -- The correct discount rate for public projects has been a subject of continuing debate. However, there is consensus that it is less than the average rate of return to private capital, and more than the rate of interest implied by consumer saving behaviour. Some estimates have placed it around a real interest rate of 10% (real means without inflation).

    Partial Equilibrium Concerns:

    - -- The discount rate should be stated in "real" terms. This means that inflation should not be included; and
    - -- The discount rate should be applied to "real" numbers. The effects of anticipated inflation should be removed before discounting. If the base year is 1986, then all future costs and benefits should be stated in 1986 dollars before discounting.

    General Equilibrium Concerns:

    - -- Risk adjustment. If appropriate, the discount rate should be adjusted for risk. "Risk" in this case is not the uncertainty of project costs or benefits. Instead, it an adjustment made if the net benefits of the project are unusually highly correlated with the health of the economy; and
    - -- The correlation should be unusually high because all transportation projects will have net benefits correlated with the economy. This adjustment is rarely done.
- **Was net present value used as the decision criterion? If net present value was not used, as in a cost-effectiveness study, was the case established that the net present value could be expected to be positive?**
  - -- Net present value is the only correct criteria for judging whether a project is worth undertaking. Internal rate of return and benefit to cost ratios are known to be inferior. Using them may result in accepting bad projects and rejecting good ones. If capital funds are limited, and all

projects with positive net present value cannot be funded, then the correct approach is to fund those projects with the highest net present value per dollar of investment; and

-- On occasion, a full Benefit-Cost Analysis study is not done. Instead, the objective of the investment is assumed to be worthwhile, and the most cost effective means of providing the investment's function is sought. In these cases, it should be demonstrated that there is strong reason to believe that the net present value of the project is positive, even if such a calculation is not undertaken. All other criteria still apply.

° **Was the risk and uncertainty in results explored and tested?**

-- All Benefit-Cost Analysis assessments will have weak points in their data and assumptions. The sensitivity of the overall conclusions should be tested to see if alternative assumptions or variations in the data affect the conclusions. Methods to do this include sensitivity analysis, and Monte Carlo analysis; and

-- If there is substantial risk that one of the assumptions is not valid, or of an alternate value, then the estimate of net benefits should be reduced to account for this possibility.

° **Were any departures from normal standards of practice adequately explained?**

-- If there are special circumstances causing the study to vary from the criteria established above, they should be explained and justified.

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APPENDIX D
INCREASES IN CONSUMER SURPLUS FROM PRODUCTIVITY IMPROVEMENTS IN THE PRIVATE SECTOR CAUSED BY INFRASTRUCTURE IMPROVEMENT

INCREASES IN CONSUMER SURPLUS FROM PRODUCTIVITY IMPROVEMENTS IN THE PRIVATE SECTOR CAUSED BY INFRASTRUCTURE IMPROVEMENT

This appendix develops a method to calculate the increases in consumer surplus resulting from a road network improvement. It assumes that the road network improvement has impacts on private sector productivity. For example, transportation intensive firms are expected to alter their logistics and operations to take advantage of the network improvements. The typical reaction would be to reduce stocking points and increase the distance travelled by vehicles distributing goods. This model may be applied generically to any infrastructure investment creating productivity improvements among firms which make use of it.

The network improvement is expected to shift demand curve. The change in consumer surplus to be estimated arises from a lowering of transport costs and the simultaneous shifting of the demand curve. To make the estimation, the new and old demand curves are estimated using available data.

The model assumes linear demand curves, and uses elasticities as inputs. To assist in interpretation of the models, it is helpful to note the following general rules. Consider a demand curve

$$P = a + bQ$$

where P and Q are price and quantity and a and b are parameters. If η represents own price elasticity of demand evaluated at (P_0,Q_0), then

$$b = P_0/\eta Q_0 \quad (1)$$

$$a = P_0 - P_0/\eta \quad (2)$$

$$P = (P_0 - P_0/\eta) + (P_0/\eta Q_0)*Q \quad (3)$$

AVAILABLE INFORMATION

The following information is assumed to be available. Units are stated generically as "physical units of use" and "cost per physical unit of use". For convenience, these may be thought of as vehicle miles and cost per vehicle mile.

VM_0 = Current use of infrastructure in physical units

C_0 = Current user cost per physical unit

N = Absolute value of elasticity of demand in physical units with respect to user cost

DVM = % change in physical units required to provide same volume or level of service

DC = % change in operating costs per physical unit given current volume or level of service.

Note that DC includes both direct *savings per physical unit, and the effective savings from inventory* reductions or other productivity improvements expressed on a per physical unit of use basis. That is,

DC = %Direct savings per physical unit
+ Total other savings/C_0*VM_0(1+DVM)

The inclusion of DVM in the second term above is to express the savings per physical unit, based on the use of transport after.

ASSUMPTION OF CONSTANT RETURNS TO SCALE IN TRANSPORTATION

The per unit cost of transport is assumed not to vary with volume of traffic. This is a conservative assumption with respect to estimating net benefits of investment, since costs will tend to fall as the volume of transportation business expands. Cost will tend to fall because of the economies of scale in serving greater volumes within a given delivery area.

The assumption of economies of scale is made to simplify information requirements. It is possible to improve the algorithm to account for scale effects of transportation.

THE INITIAL DEMAND CURVE

The initial demand curve is defined by a line passing through the initial volume of road use and the cost per unit of use (VM_0,C_0). The slope of the line is defined by the given elasticity (N). By (3), we may state the initial demand curve as

$$C = [C_0+(C_0/N)] - [C_0/(N*VM_0)]*VM \tag{4}$$

THE NEW DEMAND CURVE

To find the new demand curve, define S as the underlying product being produced by transport using firms. For example, if vehicle miles is the unit of road use, then tons delivered might be the product. We may use our freedom of choice in defining units to define S so that, prior to the improvement in the road network, ($S_0 = VM_0$). In other words one S is the average number of tonnes delivered per vehicle mile. By our assumption of constant returns to scale we may state that before the road improvement.

$$S = VM \tag{5}$$

Any change in VM implies a proportionate change in tonnes delivered. Because of the choice of units, we may also say that the cost of providing a unit of S, CS, is equal to the operating cost for a vehicle mile. Therefore, prior to investment in the road network,

$$CS = C$$

From (5) and (6), the implied demand curve for the underlying service (S) is the same as the demand curve for vehicle miles.

$$CS = [C_0+(C_0/N)] - [C_0/(N*VM_0)]*S \tag{6}$$

The slope, intercept, and price elasticity of (6) are the same as (4) as well. Now, after the road improvement, firms are still providing the underlying service S, however, they have made a substitution between transportation and stocking points, so that it takes more vehicle miles to deliver the same amount of S. The new relationship is

$$S = VM/(1+DVM) \tag{7}$$

The cost of a unit of S has also changed. Since it takes more vehicle miles to deliver S,

$$CS = (1+DVM)*C \tag{8}$$

Since the demand for the underlying service provided by transportation using firms has not changed, we may insert (7) and (8) into (6), to obtain the revised demand curve for infrastructure use.

$$(1+DVM)*C = [C_0+(C_0/N)] - [C_0/((N*VM_0)*(1+DVM))]*VM \tag{9}$$

or

$$C = [(C_0+(C_0/N))/(1+DVM)] - [C_0/((N*VM_0)*(1+DVM)^2)]*VM \tag{10}$$

(10) is the demand curve for infrastructure use after the investment in the road. The new value for C is known from the initial data as

$$C_1 = C_0*(1-DC) \tag{11}$$

To find the after investment use of the infrastructure, substitute (11) into (10) and rearrange.

$$VM_1 = [[(C_0+(C_0/N))/(1+DVM)] - C_0*(1-DC)] / [C_0/((N*VM_0)*(1+DVM)^2)] \tag{12}$$

CALCULATING SURPLUS

Before investment, the area under the demand curve is given by the integral of (4), less the total cost of transport (C_0*VM_0).

$$SPLUS_0 = [C_0+(C_0/N)]*VM_0 - .5*[C_0/(N*VM_0)]*VM_0^2 - C_0*VM_0 \tag{13}$$

After investment, the area under the demand curve is given by

$$SPLUS_1 = [(C_0+(C_0/N))/(1+DVM)]*VM_1 - .5*[C_0/((N*VM_0)*(1+DVM)^2)]*VM_1^2 - C_0*(1-DC)*VM_1 \tag{14}$$

where the value of VM_1 is given by (12). Net benefits of the increase infrastructure are the difference between the two consumer surplus'.

$$NET\ BENEFITS = SPLUS_1 - SPLUS_0 \tag{15}$$

A SIMPLIFIED VIEW

A simpler way to approach to estimation may be found if we use the demand curve for the underlying service S, instead. From (8):

$$CS = [C_0+(C_0/N)] - [C_0/(N*VM_0)]*S \tag{6}$$

Since the demand for infrastructure is derived from the demand for the underlying service, the area under the demand curve will be the same, as will any changes in surplus. Since there is no shift in the demand for the underlying service, the increase in surplus from highway improvement will come from the reduction in the cost of providing S. The initial cost of S is

$$CS_0 = C_0 \tag{16}$$

The impact of the road improvements on CS is to reduce it by the reduction in the cost per vehicle mile, but increase it by the increased vehicle miles used. Therefore, the after investment cost of S is

$$CS_1 = C_0*(1\text{-}DC)*(1+DVM) \quad (17)$$

The gain in surplus is given by the shaded area in A-1. Had restructuring being disregarded, the effective price reduction per unit of S would have been underestimated at SC', resulting in the smaller area (a+b) of Figure A-1. To estimate the net benefits we may use the area of a square plus the area of a triangle.

$$\text{NET BENEFITS} = (CS_0\text{-}CS_1)*[S_0+.5(S_1\text{-}S_0)] \quad (18)$$

Simplifying:

$$\text{NET BENEFITS} =.5*C_0*[1\text{-}(1\text{-}DC)*(1+DVM)]*(VM_0\text{-}S_1) \quad (19)$$

where S_1 is given by a rearrangement of (6)

$$S_1 = \{[C_0+(C_0/N)] - C_0*(1\text{-}DC)*(1+DVM)\} / [C_0/(N*VM_0)] \quad (20)$$

Note that it is not necessary to define or know the unit what the underlying service S is in order to apply this method.

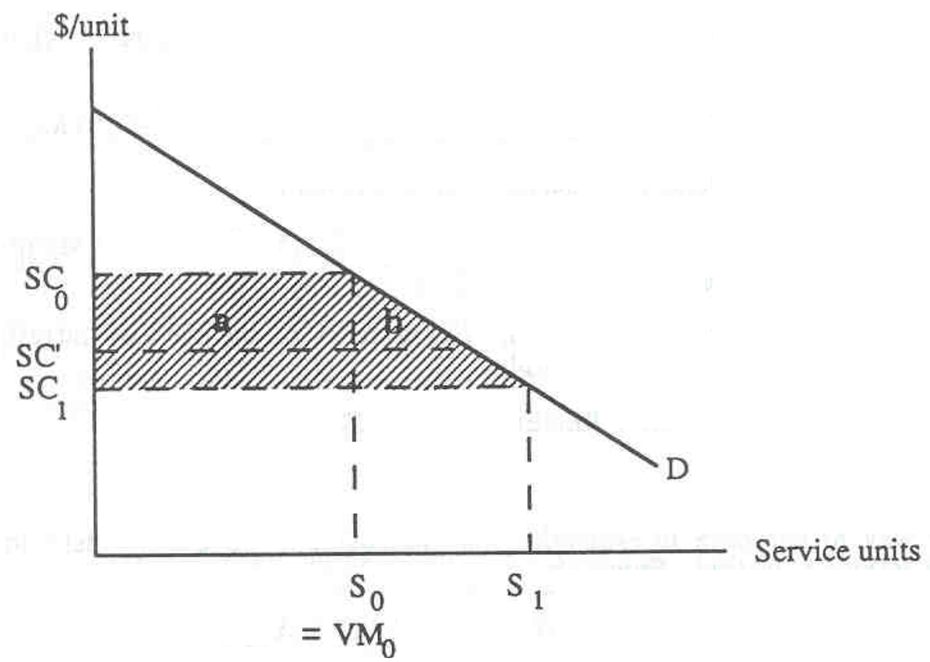

FIGURE A-1
SIMPLIFIED APPROACH

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APPENDIX E
PRODUCTIVITY ESTIMATION COMPUTER MODEL: USER GUIDE

A diskette containing the Productivity Estimation Computer Model, described in Appendix E, is available from TRB for $5.00. A check or money order, payable to Transportation Research Board, must accompany all orders. Payment may be made by check or money order (payable to Transportation Research Board) or by VISA, MasterCard, or American Express. Only charge-card orders will be accepted by telephone (202/334-3214) or fax (202/334-2519). Be sure to include expiration date. Mail orders to:

Transportation Research Board
Box 289
Washington, DC 20055

PRODUCTIVITY ESTIMATION COMPUTER MODEL: USER GUIDE

INTRODUCTION

The Productivity Estimation Computer Model is designed to account for the benefits of infrastructure investment that cannot be captured by Benefit-Cost Analysis as currently practiced. These benefits accrue to firms when they restructure their operations to take advantage of logistic and technological changes made possible by infrastructure improvements. the benefits can take the form of economies of scale in handling (volume economies), inventory savings, economies from the elimination of stocking facilities and so on. (Such logistical and technological changes are called productivity improvements because they reduce logistics costs to the firms for any given level of service.)

The model uses market consultation and survey data as inputs; the inputs are chosen to represent information on the market, and the restructuring intentions of firms, in the context of a prospective infrastructure investment. The data are combined with a series of established economic relationships so as to estimate the impact of logistic and technological restructuring on infrastructure demand.

The outputs generated by the model include both the investment benefits inclusive of private sector productivity improvements, and the investment benefits as calculated for current Benefit-Cost Analysis practice. This resulting information enables the practitioner to isolate productivity improvements from investment in infrastructure, i.e. to assess the extent to which the benefits from infrastructure investment are underestimated by current practice.

> The methodology presented here offers an indicative approach to measuring the impact of infrastructure improvements on private sector productivity. The method represents a preliminary framework which is now being examined, improved and finalized under NCHRP Project 2-17(4).

The remainder of this Appendix provides instructions concerning the installation and application of the Productivity Estimation Computer Model. It also offers basic information on entering input data into the program and generating results, and provides a limited discussion of the technical nature of the inputs.

The Appendix is organized as follows: the first section outlines the installation procedures; the second section discusses program application;a nd the third section explains each item from the main menu.

Readers should use Chapter 14 together with this Appendix in order to fammiliarize themselves with the approach.

INSTALLATION

Included is one 5.25 inch normal density diskette. On the diskette is a Lotus 1-2-3 file named PSPIMOD4.WK1 which contains the entire model. The model can be run either from a hard drive or directly from the attached diskette. For users who prefer to run the model from the hard drive, the suggested installation procedure is a follows:

- Create a directory named \PRODUCTY on the hard drive; and

- Copy the PSPIMOD4.WK1 file from the diskette to the \PRODUCTY directory on the hard drive.

APPLICATION

In order to start the model, the user must:

- Start the Lotus 1-2-3 program;
- Make \PRODUCTY the current directory using the \FILE DIRECTORY command; and
- Retrieve the PSPIMOD4.WK1 worksheet using the \FILE RETRIEVE command.

After following the above three steps, the program will respond with the main Transportation Productivity Impact Estimation Model screen. a menu will be presented, from which all items are available to the user except RISK (which is discussed below).

MAIN MENU

The main menu of the Transportation Productivity Impact Estimation Model contains the following items:

INPUTS OUTPUTS GRAPH PRINT SAVE RISK EXIT HELP

Each of these menu items is described below. The user can select an entry by moving the highlight bar with the cursor control key and hitting **ENTER** or typing the first letter of the selection. It is recommended that the user first select the **HELP** item to get a quick overview of model terminology and functions. Unless otherwise indicated, the user should follow the instructions that appear on each menu item screen.

INPUTS allows the users to enter the input data necessary to calculate the benefits form infrastructure investment. The first screen prompts the user to enter firm-specific data on infrastructure use.

The second screen prompts the user to enter estimates of the impact of the investment on firm operations. Three categories of impact estimates can be specified:

1) Change in Physical Units Required to Provide Same Volume or Level of Service;

2) Reduction in Operating Costs per Physical Unit Given Current Volume or Level of Service (if restructuring); and
3) Reduction in Operating Costs per Physical Unit Given Current Volume or Level of Service (if no restructuring).

Input (1) is specified as the anticipated change in physical units required to provide the same volume or level of service given restructuring of the firms operations. Input (2) is specified as the anticipated reduction in operating costs given restructuring of the firm's operations. Input (2) includes, in addition to the time and fuel savings usually calculated, the anticipated structural savings from restructuring, such as economies of volume, inventory savings, elimination of stocking facilities, etc. Finally, input (3) includes time and fuel savings only, assuming no restructuring of the firm's operations-the inputs that are necessary for standard benefit-cost analysis of infrastructure investment proposals.

OUTPUTS allows the user to view the results of the model run using the inputs provided in **INPUTS.** The first screen shows the amount of investment benefits calculated according to Benefit-Cost Analysis as currently practiced. These benefits are calculated using only input (3) above and the initial curve.

The first screen also shows the amount of investment benefits according to the method incorporating productivity impacts (Method 1). This method calculates benefits using inputs (1) and (2), the initial demand curve and the new demand curve for infrastructure.

The second screen shows the amount of investment benefits according to an alternative method (Method 2) which yields results that are identical to those from Method 1. Method 2 uses a standardized service unit (the underlying service), such as the number of vehicle-miles under the old technology-i.e. prior to restructuring. After restructuring, each service unit is cheaper. The cost reduction is in part attributable to time and fuel savings, and to the logistic and technological improvements (which lower the cost of providing the same volume or level of service as before).

GRAPHS gives a graphical representation of the model's results. Using the values provided in INPUTS, the first graph shows the benefits, traditionally measured, as the additional area under the demand curve for infrastructure use. the second graph shows the benefits including restructuring which includes the additional impacts represented by the shift of the demand curve.

PRINT allows the user to send a copy of the Input and Output Screens from the last run to a printer. the user should consult the **HELP** menu to change printer set up or customize the printing.

SAVE enables the user to save the model (incorporating the inputs and outputs from the last run). The user should consult the **HELP** menu to change the default file name and/or directory for saving.

RISK in order to apply risk analysis to the model, additional software wi required at this time. Two software packages providing this additional capability are: 1) Hickling's Risk Analysis Process, and 2) Palisade Corporation's @Risk -- Risk Analysis and Simulation Add-In for Lotus 1-2-3. Each can be easily incorporated with the software presented here.

HELP provides interactive user help for each menu item discussed in this section, including the one that follows.

EXIT enables the user to leave the model menu. The user can then either start a normal Lotus 1-2-3 session, change **SAVE** or **PRINT** settings, or customize the model.