APPRAISING TRANSPORTATION RESEARCH

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Abstract

Public sector involvement in research is examined, with emphasis on the creation of incentives by government. In transportation, government investment in research is often a spark for improvements in overall economic productivity. This connection has been dubbed "the Virtuous Circle" and helps justify basic and applied research.

Is research always justifiable from a societal perspective? The answer to this question is best approached with the application of cost-benefit analysis, or more specifically net present value (NPV). While NPV appears to be simple calculation yielding transparent solutions, a proper cost-benefit analysis requires careful construction of a base case as well as decisions on discount rates and indirect impacts. Sensitivity analysis is used to check the validity of the chosen assumptions. A case study of new, high speed rail technology illustrates how some of the concepts can be applied.

APPRAISING TRANSPORTATION RESEARCH

Research in transportation changed dramatically during the 1980s. Interest in transportation waned at the beginning of the decade: funding declined in real terms, enrollment in university courses dropped, and private research firms were diversifying. Deen (1) observed that research expenditures had fallen between one-tenth to two-tenths of a percent of total spending in surface transportation modes and that technological improvements were being neglected. Astute lobbying reversed this decline by the end of the decade. Beginning with the Strategic Highway Research Program (1987), a series of new federal research and development initiatives were authorized. This has included, among others, the Program to Automate the Highway (1987), University Research Centers (1987), the Highway Safety Act of 1987, funding for Intelligent Vehicle-Highway Systems (1991) and increased funding for both the cooperative highway and transit research programs.

The recent fortunes of transportation research have changed dramatically. Between 1989 and 1992, federal funding for transportation research has increased by 14.9 percent in real terms. Funding by state agencies has also increased although the magnitude is unknown. Possibly the best indicator of the change is to be seen in the Highway Planning and Research Funds available to states and federal agencies, which doubled from $150 million in 1987 to $300 million in 1992.

A new dilemma now faces managers of transportation agencies; how to allocate the funds efficiently. This article, based upon research requested by the California Department of Transportation (Caltrans), considers research as an investment. A rationale for government investment is presented together with various approaches to research sponsorship. Techniques for developing and appraising R&D (Research and Development) proposals are considered with the recommendation that the Net Present Value method for investment evaluation be used. An example for rail technology is used to illustrate the approach. Additional examples as well as a methodology for appraising a portfolio of R&D proposals are included in the final report (2).

THE CASE FOR PUBLIC SUPPORT OF R&D

Economists justify government support for research with market failure arguments. Firms are not sufficiently rewarded for undertaking research activities because their profits may be substantially less than the social value of innovations. This argument rests on two attributes of research: first, a successful project results in information about new products or processes, and second, substantial uncertainty exists about the commercial prospects of a research enterprise.

Information, once it becomes public, can be used freely by people other than its discoverers. Sometimes just the knowledge that a product is feasible gives an advantage to potential competitors. The first characteristic of research implies that an innovation can be copied at much less expense than the original research or development work, so that competing firms can gain profits from the invention at a lower cost than the original innovator. This is known as the "appropriability problem"; researchers may be unable to appropriate the full returns from an invention. Indeed, it may be in everyone's interest to be a copier rather than an innovator. As a result, research will receive less attention than it should, and in some cases it might not be performed at all.

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The second attribute, uncertainty, is more subtle. The problem is not just that uncertainty over profits exist, but that risks to individual investors may be much greater than for society as a whole. When private risk exceeds social risk, firms underinvest in research activities.

Use of public resources to subsidize research is a common response to these market failures. However, while lack of appropriability and uncertainty are characteristics common to all research activities, they are particularly problematic in the supply of government services like highways and public transit where public and private investments are commingled.

Government Goods

By government goods we mean any product whose use is determined, or significantly affected by the public sector. It is important to distinguish government goods from other products in assessing R&D policy for two reasons: first, because the public sector is instrumental in their use, a range of policy options for encouraging R&D through market-pull policies are available to government that are not feasible for other products, and second, market failure problems can be severe.

Uncertainty is compounded for private companies who might be interested in improving the technology of government goods. Public decisions reflect nonprofit oriented goals; in addition, they depend on constraints not present in the private market. Purchasing decisions can reflect political imperatives: maintaining employment in a certain area, for example, or "buy American" requirements. Regulatory requirements that might be critical for establishing a market for products can shift for reasons unrelated to the actions of suppliers. For example, strict environmental requirements are sometimes relaxed during economic downturns. Furthermore, personnel shifts, either administrative or legislative, are frequently accompanied by changes in policies. Different administrations may place different priorities on public goals: for example, the desire to spur economic growth versus avoiding environmental harm caused by development. All of these factors raise uncertainty for firms, so that they become reluctant to invest in research.

Underinvestment in research for government goods arises because government cannot commit to a set of policies over time (3). Market failure is severe when the time horizon of the research project is long, because the resulting innovations are likely to be available only after the government has changed. Thus, in designing strategies to promote research for government goods, it is important to consider the relationship of the product to potential changes in policies, and to discount potential benefits according to this risk.

This section has identified a number of different market failures that can give rise to underinvestment in research. We turn next to an overview of promotional strategies available to a government agency.

PUBLIC STRATEGIES TO PROMOTE R&D

Strategies to promote research fall into two main categories: those designed to lower the cost of research, and those intended to increase the value of results. The latter are usually called "market-pull" or demand strategies, while the former attempt to increase the supply of research. Four alternatives are considered: on the supply side, direct funding of research and conducting research in-house; on the demand side, establishing prizes for innovations and creating market guarantees.

Direct Funding of Research Activities

Grants and contracts to firms and individuals form the main alternative by which government promotes research. The chief advantages of the strategy are: it is relatively easy to institute, it enables specified goals to be addressed with some precision and it allows the government to retain control over the quantity of expenditures devoted to a project. In addition, many federal cost-sharing programs are exclusively for research grants and contracts, so that an agency can only take advantage of federal programs if it institutes this method of encouraging R&D. The strategy has two main disadvantages: it puts the agency in the position of "picking winners" (both projects and contractors), and the agency is still responsible for monitoring progress. This places a substantial informational burden on the governmental agency. And in a new field like automatic vehicle control systems, few firms have track records to support proposals, and new firms may be overlooked.

Subsidies for research are alternatives to grants and contracts. The federal government gives a tax credit to firms for expenditures devoted to R&D. This policy avoids both picking winners and monitoring; alternatively, it does not allow the government to single out those areas that are more prone to underinvestment. Another related strategy is to subsidize loans to firms. The federal Synthetic Fuel Corporation guaranteed loans to selected companies that built energy demonstration programs in the early 1980s; an expanded version of this policy is currently under consideration. Subsidies have also been granted to encourage the manufacture of low-emission automobiles.

In-House Research

Another possibility is for the government agency to conduct research in house. For example, the Division of New Technology, Materials and Research in California provides in-house research and testing of materials and structures for Caltrans. In addition to avoiding monitoring problems associated with contracting out research, the strategy provides an important spillover benefit for the agency. It provides the agency with a cadre of scientists who can evaluate outside proposals and inform the agency about research opportunities. Research contracts with both state university systems and several private research institutions are managed by the Division to examine and develop innovative approaches to transportation.

A similar rationale is used by major firms who conduct basic research. A number of large U.S. firms have world class science laboratories. These companies claim that the expense of their laboratories is justified because the quality of scientific advice that they get from employees on a range of topics would not be available if they didn't provide the scientists with opportunities to conduct research as well as review and evaluate research done elsewhere.

Conducting research in-house is subject to several pitfalls. Civil service rules, and indeed, normal employment practices, make it difficult to either cut back or change employment in a short period of time. Research contracting gives an agency a level of flexibility that is difficult to duplicate when activities are concentrated within the agency. Another problem is that the agency's employees are likely to be proponents for the use of innovations developed within the agency, as opposed to technological alternatives developed elsewhere. Thus, it is probably more appropriate for an agency to undertake activities that overlap only minimally with technologies investigated in the private sector.

Prizes for Innovation

Another alternative to funding research is to give some kind of financial award to successful innovators in particular technology areas. In order for this strategy to establish incentives, the prize needs to be announced in advance. Firms conduct research and then submit the results of the research. The "best" system wins a procurement contract, which is usually lucrative. A second form of prize that government can give to firms is through standard setting. A current example is the high definition television (HDTV) "standards competition" that the Federal Communication Commission (FCC) has undertaken. The FCC has announced that it will establish a standard for HDTV that will support the best design from among several proposals that are being submitted by competing television firms. The standard will yield considerable wealth to the firm or firms that will hold relevant patents, and is thus a form of prize for research activities.

Prizes have been shown to be very effective devices for inducing private firms to expand their research activities. Selection of private consortia to construct and operate the four toll road projects as authorized by the California legislature in 1990 is an example of the prize strategy. Caltrans initiated the process by inviting firms to submit qualifications; 10 were accepted and invited to propose specific projects. Eight proposals were submitted. Although each proposal had cost private companies $1 million or more to prepare, only four were awarded franchises.

The prize strategy avoids many of the problems identified with direct research awards in that the government need not choose a research strategy, nor evaluate the qualifications of potential researchers. However, it too suffers from limitations. First, the strategy is most successful when a number of different firms can compete for the prize. For example, defense department contest results are very sensitive to the extent of competition. When procurement contracts are awarded on a noncompetitive basis (e.g., sole-sourced), they yield no measurable incentive for firms to conduct research in advance of the contract. Second, the government needs to be able to specify the particular product or application in advance. Thus, it is not a feasible strategy for the conduct of basic research. Third, the commitment to provide the prize needs to be firm. If a technology forcing regulation is modified in subsequent years, firms that invested in the original technology would be left stranded. Indeed, firms would probably discount the potential profits to reflect their assessment of the strength of the political commitment. For these reasons, commitments become attenuated over time in the political sector. The policy is probably most effective for innovations that require relatively little lead-time.

Market Guarantees

The government can guarantee a market for categories of innovations, although not for specific firms, through several mechanisms. One is technology-forcing regulations. Such regulations, which are successful in such areas as automobile emission systems, establish a future date by which products must conform to new technological standards. Another option is government procurement; this strategy yields efforts in research when firms have reason to believe that their product will be adopted by the government. As with prizes for innovation, the policy avoids problems with direct research funding, in that government need not identify which firms are likely to be successful in advance. The strategy is only available to goods whose use the government regulates or purchases in significant quantities. Since the policies need to be credibly committed to in advance, the use of this strategy is further limited to cases where the government can make a commitment, either to follow through on purchases or not to modify standards and regulations. However, this is unlikely to be an effective strategy for promoting basic research whose applications are both uncertain and only likely to be available far in the future. Market guarantees are an attractive alternative to encouraging research in areas that are likely to pay off soon (development work, in particular) and whose importance is agreed to by consensus.

Although demand side strategies for encouraging research such as prizes for innovation and market guarantees are attractive, institutional relationships of federal, state and local agencies make it more likely that transportation research will remain supply side oriented. Therefore, strategies are required that will improve the selection of contract funded and in-house research.

RESEARCH AND PRODUCTIVITY GROWTH

Research plays a critical role in productivity growth, because through R&D agencies acquire the knowledge that enables them to utilize capital investments. For any production unit, output is functionally related to the use of inputs which are conventionally categorized as labor, capital equipment, and natural resources. The functional relation between inputs and outputs represents the technology of production, the managerial and technical skill of owners and employees, and the organization of economic activity within the region.

The "Virtuous Circle"

Investment in transportation facilities can trigger productivity growth. By decreasing assembly and distribution costs, the spatial scope of competition is enlarged and management is motivated to explore improved technologies for producing goods and services. This is why R&D is critically important to productivity growth; successful innovations require additional capital and this continues the cycle.

Lewis, Hara, and Revis (4) explain the crucial role of capital investment as a "virtuous circle". They emphasize that capital investment, including the development and maintenance of transportation infrastructure, offers one of the most effective catalysts for productivity growth. Innovations from research spur better use of resources; implementation occurs through new facilities and superior operating modes that can improve productivity and contribute to economic growth. And the investment of additional capital prompts the cycle of new research and improved technology. However, not all transportation investments are necessarily beneficial. Decision makers must evaluate the net benefit of proposals before investing capital.

Lasting benefits from transportation are achieved through increased productivity. Travel time reductions may benefit commuters, and special services may satisfy the travel needs of individual groups, but the sustaining benefits are those which boost productivity by reducing costs or raising the quality of goods and services.

Economic Impacts

Overall benefits of transportation improvement are frequently obscured. They are normally expressed as the number of jobs created or the number of purchases from other sectors, whereas it is through increased productivity that real economic benefits are achieved. In addition, the influence of transportation upon personal and regional income and land use is usually omitted because of the time and cost required for this type of analysis.

Promotional literature associated with transportation improvements boasts about the number of jobs that will be created. If this logic is followed, workers would be unemployed at the conclusion of construction. A counter argument goes as follows: if the taxes had not been collected to pay for the improvement, individuals would have spent their money and created private demands for additional employment. Only in regions of chronic unemployment can a genuine case be made for transportation investment creating jobs (5). A more thorough assessment of overall benefits is made by examining the productivity increases derived from transportation investment. Elimination of congestion reduces travel time and translates into real improvements in productivity, allowing firms to reduce costs. Improved productivity stimulates the economy and encourages the hiring of additional employees. For example, a supermarket chain owning stores and warehouses across the country will benefit from highway improvements through reduced travel time for trucks. This sort of benefit has been described by Quarmby (6) for the Sainsbury supermarket chain in the United Kingdom.

COST-BENEFIT ANALYSIS AS A TOOL FOR DECISIONMAKING

For a state to remain competitive in an expanding global economy, research and development must be an integral part of the commitment to economic growth. In this respect, transportation research serves a twofold role: it is a way in which agencies may look into their own future to set a strategic course, and it is a way to improve the efficiency of existing operating systems.

Despite recent increases in the funding available for transportation research, the current financial climate imposes strict constraints upon the allocation of funds. Agencies and firms can no longer invest money in research without clear objectives and knowledge of probable outcomes; therefore, techniques like cost-benefit analysis (CBA) are required to examine the merits of, and guide the choice between, competing proposals. Although widely used in transportation, CBA is seldom employed correctly, and special care is required in order to avoid errors. The following requirements are essential:

- Uniformity in assessments across proposals must be preserved. Cost-benefit analysis relies upon the art of arranging uniform assessment of alternatives. This may entail the sacrifice of information available for only some alternatives.
- Goals must be defined in operational terms together with the rate of return that is expected from transportation investments.
- A base case, using the best available practice, must be defined so that there is a datum against which future improvements can be measured rather than the "do nothing" case.
- Timing of costs and benefits must be estimated and values discounted to current dollars.
- And results should be tested for sensitivity to changes in critical assumptions, such as the rate of discount.

Cost-benefit analysis creates a ranking among competing alternatives that is best used as one input into the complete decisionmaking process. The criterion used for this ranking is that of maximizing monetary return (benefits) for a given amount of money invested (costs). Quantifiable estimates are preferred, but qualitative estimates can be used and the ranking can be integrated with other criteria to create a measure based upon different goals. For example, Gosling and Jackson (7) describe a methodology used by the Wisconsin Department of Transportation to allocate funding among projects. The methodology consists of an equal weighting between cost-benefit results and the goal of political acceptability.

Cost-benefit analysis comes in a number of forms which differ in the way costs or benefits are expressed. The most common forms are cost-effectiveness analysis, benefit-cost ratio, internal rate of return and Net Present Value (NPV). The merits of each are discussed by Mishan (8). We focus here on NPV.

Net Present Value

The recommended method for expressing the relationship between costs and benefits of research is net present value. This criterion is similar to the benefit-cost ratio, but expresses the result in current dollars rather than a ratio. The formula is written as:

$$NPV = \sum_t (B_t - C_t)/(1+r)^t$$

where B are benefits, C are costs, r is the discount rate (or the rate at which money could be invested elsewhere in the economy) and t is the number of time periods considered, usually the projected lifetime of the particular project.

The larger this value, the more a project improves welfare. Expression of the result in current dollars is a real advantage for decision making, and most of the information required to calculate NPV is available from the same data used to calculate cost-effectiveness studies. Lewis (5) illustrates the superiority of NPV by recalculating the results from an UMTA sponsored study that appraised four transit alternatives in reference to the goal of lowering "cost per new transit rider." The results are instructive; whereas the cost effectiveness study appraisal favors the light rail option, NPV shows that no alternative yields a positive net benefit over a specified base case which entailed using existing infrastructure more effectively. However, the results would change if different discount rates were used, or if a longer project life was assumed.

These cautions are appropriate; NPV, like other methods of CBA, is a technique for appraising similar proposals. It is one element to be considered in the complete decisionmaking process. It should not be used to predict the actual financial outcome of a proposal or project.

Advantages of NPV

Although four methods, cost-effectiveness, benefit-cost ratio, internal rate of return and NPV are frequently used in transportation, this does not imply that they yield the same information. Both cost-effectiveness and benefit-cost ratio neglect the magnitude of the benefit component. This omission can be confusing as the following example illustrates. Assume that there are two proposals:

Proposal 1) $5 in benefits: $1 in costs.
Proposal 2) $1200 in benefits : $1000 in costs.

By the benefit-cost ratio criterion, Project 1 is preferable. For every dollar in cost, the small project generates $5 of benefits. But Project 2, which has a benefit-cost ratio of 1.2, yields $200 in net benefits (benefits minus costs), a substantial improvement on the $4 in net benefits generated by Project 1.

Using the NPV criterion, Proposal 2 is preferred. From a societal perspective, $200 in net benefits is superior to $4. NPV takes into account the size differentials between projects and removes biases towards smaller projects. Only when projects have similar benefits and costs do the two methods yield comparable information (9).

COST-BENEFIT ANALYSIS FOR RESEARCH

Cost-benefit analysis is not a flawless tool for evaluating research proposals. The following is a discussion of some of the most common concerns, including: 1) base case specification, 2) incorporation of indirect impacts (general equilibrium), 3) discount rate, and 4) sensitivity analysis.

The Base Case

Perhaps the most important issue facing the decisionmaker in choosing among research proposals is the selection of the base case, a scenario wherein no *new* project is chosen. This does not mean the comparison is made to a situation where the agency does nothing. On the contrary, the base case scenario should include predicted improvements in current managerial practice and physical infrastructure. For example, the base case for the transit comparison in Lewis (5) assumed a traffic management system that would facilitate the use of streets by transit. Comparison of the capital intensive alternatives was based upon the improvements over the best, current managerial practice. Without designation of a base case, which happens frequently, assessment of benefits is exaggerated.

Indirect Impacts

General equilibrium impacts in transportation refer to benefits (or costs) which result as a consequence of increased ease of movement for both goods and people. These impacts include the technical changes in industry which transportation improvements allow that create improved productivity. General equilibrium impacts are seldom consistently accounted for in CBA.

Travel time savings are frequently used as a surrogate for general equilibrium benefits in transportation, but the efficiency gains that travel time savings encourage are normally omitted, resulting in the underestimate of total benefits (10). Quarmby (6) references case studies from the grocery industry in Britain indicating that productivity gains accruing to the industry as a result of travel time savings by commercial vehicles tend to be underestimated by some 30-50 percent. Omitted benefits are those achieved through economies of scale.

Collection of data is the primary pitfall for most analyses of indirect impacts. The necessary data is frequently either costly or impossible to collect, and value judgements have to be made as to what kind of data is sufficient to account for general equilibrium effects or what kind of proxy data will suffice. Rather than requiring that all indirect impacts be included, it is more important for comparison that competing alternative proposals incorporate the same types of data.

Choosing a Proper Discount Rate

Cost-benefit analysis requires that all elements of the calculation be in a common time frame. The way to do this is through discounting. This section examines some issues involved in discounting.

Discount rates should be in real terms, i.e., corrected for inflation. Furthermore, these rates ideally are adjusted for risk, where risk in this case refers to a project's correlation with the overall health of the economy. It would be simpler if a financial risk of this type could be avoided so as to take away any economic biases (such as economic growth or decline) which may occur over the entire duration of a benefit and cost stream.

For federal agencies, Lind (11) reports a ten percent real rate of discount as standard. Ten percent is roughly equal to the return on private capital in the United States economy. A case could be made for a reevaluation of this rationale for discounting, given the nature of international capital markets. An open economy has various implications for private investment returns, the most important of which is that the prevailing rate of return in the home country may not be the highest or best return to private investment. Thus, in a single country, interest rate is no longer applicable as an indicator of the appropriate discount rate. Lind advocates using not only an equilibrium world interest rate as the discount rate, but also the consumer borrowing rate at home to measure investment as well as consumption effects in CBA.

Hartman (12) describes discount practices in the Congressional Budget Office (CBO) and gives a different rationale for the choice of a discount rate. The government is described as viewing its investment projects in terms of opportunity costs, or the cost of the next best (or possible) alternative. With this perspective, the CBO judges the proper rate of discount to be a time adjusted consumption preference rate. Hartman suggests that this can be approximated by government security yields.

An agency should be cautious in choosing the discount rate for project evaluation. The structure of financial markets implies that the national opportunity cost of capital (interest rate) may no longer be a useful guide for making decisions in a regional context. Some measure of time preference, like the consumer borrowing rate, should also be used to discount projects. Since these rates may vary widely, it is essential that the analyst perform sensitivity analysis to examine the effect of rate changes on cost-benefit rankings.

Sensitivity Analysis

Sensitivity analysis analyzes how a project ranking will be affected by changes in assumptions or variables such as the discount rate. Its main strength is its simplicity of implementation and interpretation. Modifying CBA in this manner allows the analyst to note how changes in discount rates affect the choice between risky and non-risky projects.

Preference for present consumption implies that research projects with their longer benefit time horizons are risky investments. Imposing standard capital-budgeting discount rates invariably biases against research. Sensitivity analysis, however, allows research projects to be compared to other non-research projects using different discount rates to see whether research achieves a positive NPV under different assumptions. As research projects with long-term horizons appear to be sound investments only when lower rates of discount are used, shorter term, demonstration proposals, with high payoffs can be used in conjunction with them to constitute a risk-minimizing portfolio of research investments.

CASE STUDY: HIGH-SPEED RAIL

As part of the final report for the California Department of Transportation a case study was completed to determine whether additional research on high-speed trains between Las Vegas, Nevada to Anaheim, California would be worth the cost. For the purposes of comparison, value of travel time saved was used as the societal benefit derived from implementation of this technology. *Caltrans needs to decide whether the speed difference offered by alternative technology is worth the cost of the research required to adapt technology to local requirements.*

After choosing a base case comprising an electric tilt train (called the X2000) used in the Northeast United States, a comparison was made to an existing advanced technology (the TGV or Very High Speed train used exclusively in France). In order to encompass all alternatives, MAGLEV (magnetic levitation) was included as an example of the riskiest technology foreseeable for high speed rail travel. The case study focused exclusively on the net present value of the travel time savings of the three technologies between the years 2000 and 2015. A discount rate of 10 percent was used. MAGLEV and TGV were found to have $392 million and $97 million respectively of time savings benefits over the X2000.

Neither the suitability of these technologies nor the cost of implementation were studied. Rather, the case study assessed the potential value of time savings and whether these were sufficient to justify additional research.

Travel time savings between Anaheim and Las Vegas were calculated based upon the estimated best travel time of seven hours using current available Amtrak schedules. TGV would save 11.82 minutes per trip over the base case, while Maglev would save 33.72 minutes. See Table 1.

TABLE 1 Time Savings in Minutes to Las Vegas

X2000	TGV	Maglev
278.94	290.76	312.66

While these numbers are helpful, they should be converted to monetary form. Assuming a value of time of $6.35/hour in 1987 and a five percent inflation rate, the value of time in the year 2000, the target date to begin operation, is $11.97/hour ($0.1995 per minute). By multiplying the time saved by the value of time and the projected number of passengers over a fifteen year period, we come up with the Present Value of Benefits attributable to the reduction in travel time for each system.

The projected ridership for the year 2000 has been calculated for the TGV and Maglev systems (13). The difference in ridership between the two is approximately 13,286 passengers per year for each mile per hour speed difference. Given this data, ridership for the X2000 in the year 2000 can be established. Since the X2000 runs at an average speed thirty miles per hour slower than the TGV, about 398,571 fewer passengers are expected.

TABLE 2 Projected Ridership for the Year 2000 (one-way trips)

X2000	TGV	Maglev
1,811,429	2,210,000	3,140,000

Annual ridership over the fifteen year period from 2000 to 2015 is estimated by increasing ridership proportional to a 2 percent population growth rate for the state of California.

Using the value of time estimated for the year 2000 ($0.1995 per minute) and the projected ridership of the three technologies over 15 years, the Net Present Value (in year 2000 dollars) of time savings can be calculated (see Table 4). The Present Value of time savings for TGV is about $97 million greater than the time savings for the X2000, and the Maglev exceeds TGV technology in time savings by about $295 million and the X2000 technology by $392 million.

TABLE 3 2000-2015 Ridership of the Los Angeles-Las Vegas Corridor

X2000	TGV	Maglev
22,763,743	41,192,821	58,527,354

Potential savings of this magnitude indicate the desirability of additional research. The magnitude of expenditure should be determined after the sensitivity of potential time savings is examined.

TABLE 4 Present Value of Time Saved (over the base case) from 2000-2015 (year 2000 dollars)

TGV	Maglev
$97,136,379	$392,376,276

Sensitivity Analysis (this Case Study)

By changing the value of benefits the net present value of additional research can be altered. For example, estimates for value of time saved are the least reliable. We chose a 5 percent annual rate for increases in the value of travel time savings. For the period 2000-2015, estimated savings over the base case (X2000) are $97,136,379 for TGV and $392,376,276 for Maglev (Table 4).

If a 3 percent rate for growth in travel time benefits were used, the value of travel time savings would be $75,631,667 and $305,509,347 respectively. Therefore it is appropriate to report a range for the potential travel time savings of Maglev between $305 and $392 million, using the year 2000 as the base year.

Maglev is still in the experimental stages; and a state agency requires guidance on how much should be allocated for additional research and development. Although Maglev offers the highest potential travel savings, uncertainty exists over design requirements and environmental impacts. Guidance on appropriate levels of research expenditure can be obtained by comparisons with other industries operating under similar risk. The motor vehicle industry for instance, spent an average of 3.6 percent of net sales on research during the 1980's. This seems like a reasonable standard. If travel time savings over 15 years are accepted as a proxy for revenue in this period - another reasonable assumption - then research expenditure on high-speed ground transportation of between $11 million and $14 million is warranted.

CONCLUSIONS AND RECOMMENDATIONS

Despite the extensive use of CBA by transportation agencies, many studies are deficient; they fail to comply with the basic requirements for economic analysis. A recent Transportation Research Board report (5) examines 35 case studies and describes only 6 as "adequate". Failure to discount costs and benefits correctly or to use sensitivity analysis to accommodate risk and uncertainty were the most common omissions. Such errors are avoidable because most of the inadequate studies contained data that would have allowed the deficiencies to have been corrected.

Using NPV to create a fair and consistent CBA is a matter of trying to account for items and effects mentioned below:

- *Goals* for research should be preestablished together with the rate of return that decision makers expect from transportation investments.
- *Base case.* Most transportation research is applied; it seeks to make an incremental improvement in current practice. Definition of current practice should include use of the best available practice, otherwise the benefit from the research will be exaggerated.
- *Costs.* All costs should be included and not only those used to finance the research. Relevant costs would include any negative effects on the environment and employment.
- *Benefits.* All benefits should be identified. They should include direct savings as well as indirect impacts (general equilibrium effects) on the economy achieved through any restructuring that may result from the research.
- *Discounting.* All benefits and costs should be projected for the duration of the *longest* proposal under review. And they should be calculated to present-day values by applying the discount rate agreed to as a goal for transportation research.
- *Sensitivity analysis should be conducted to assess the robustness of results.* CBA involves assumptions about likely costs and benefits and probable discount rates. Results should be tested against the most likely range for the critical assumptions. At a minimum, the effects of changes in projected travel demand and cost inflation should be examined as this will expose uncertainty that may be inherent in the proposals.

Recommendations for CBA studies in this report should be viewed as a new outlook on a familiar framework rather than a new methodology. The procedures are well known, though seldom followed. The standard procedure provides an economic basis for any agency wishing to implement efficient and fair research allocations within increasingly limited budgets.

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